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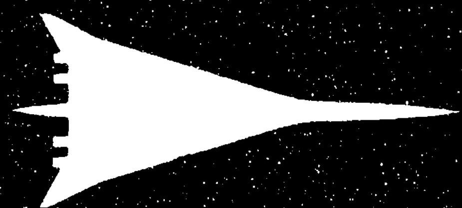
CONTRACT NUMBER FA-SS-65-20

NASA SCAT 15-F FEASIBILITY STUDY



D6-16325

MAY 1965

FEDERAL AVIATION AGENCY

THE BOEING COMPANY
AIRPLANE DIVISION

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NOTICES

The information contained herein is a part of the supersonic transport research program sponsored by the Federal Aviation Agency with technical support provided by the Department of Defense and the National Aeronautics and Space Administration.

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[redacted]

ILLUSTRATIONS

ILLUSTRATIONS
(Continued)

ILLUSTRATIONS
(Continued)

TABLES

1.0 INTRODUCTION

This report is submitted in response to the January 22, 1965 amendment to Boeing-FAA Contract No. FA-SS-65-20. The specific amendment states:

> "An additional approach to the feasibility of a fixed wing configuration supersonic transport is desired. Accordingly, a study will be conducted of a supersonic transport based on the NASA SCAT 15F aerodynamic configuration. The study will include attention to aerodynamic performance, stability and control, structural design, sonic boom parameters and weight analysis to determine the practicality of this design approach. Manufacturing feasibility studies will also be conducted to evaluate the potential of this design approach."

The configuration submitted to Boeing for evaluation was the NASA SCAT 15F-220, having a wing area of 9,150 square feet, an estimated gross weight of 430,000 pounds, and an estimated payload of 43,000 pounds. Wind tunnel data was furnished to Boeing by the NASA Langley Research Center on the SCAT 15F-150 concept, having a wing area of 6,954 square feet, an estimated maximum taxi gross weight of 400,000 pounds, and an estimated payload of 30,000 pounds. Because of the difference between the two airplanes, the furnished data was evaluated and modifications made to develop a revised configuration.

The SCAT 15F configurations studied by Boeing have been:

Boeing Designation	
SCAT 15F-B1	Identical to NASA configuration, SCAT 15F-220; 198 passenger, capacity-limited payload (90 percent tourist, 10 percent first class).
SCAT 15F-B2	Identical to -B1 except body adjusted for 215 passenger, capacity-limited payload.
SCAT 15F-B3 to -B6	Study configurations with variations in longitudinal trim and control surfaces.
SCAT 15F-B7	Final configuration, 500,000 pounds Ramp Gross Weight, 560 pounds/second General Electric engines.
SCAT 15F-B8	Parametric configuration identical to -B7 except 585,000 pounds Ramp Gross Weight and 760 pounds/second General Electric engines.
SCAT 15F-B9	Parametric configuration identical to -B7 except 525,000 pounds Ramp Gross Weight and 730 pounds/second Pratt & Whitney engines.

[redacted]

2.0 SUMMARY

In January 1965, the FAA directed Boeing to study the feasibility of a fixed wing supersonic transport. The concept was to be based on the NASA Langley SCAT 15F-220 (SCAT 15F-B2, Fig. 2-1) with an estimated supersonic cruise lift-drag ratio of 9.5.

Sizing studies with the SCAT 15F configurations, as evolved during the study, are summarized in Table 2-A and compared with the variable sweep Boeing Model 733-290. It has not been possible to simultaneously meet all the FAA design objectives with the SCAT 15F concept. The results of the study indicate that the FAA objectives for airport and community noise, takeoff and landing speeds must be relaxed to make the concept feasible. The relatively poorer low speed aerodynamic characteristics cannot be compensated by larger wing area or engine size without an excessive weight penalty. A low-speed canard (retracted in cruise) has been added to the NASA configuration in order to allow maximum use of high-lift trailing edge flaps. The SCAT 15F-B7 (Fig. 2-2) at a ramp gross weight of 500,000 pounds using maximum augmented power for takeoff, has a D.O.C. comparable to the 733-290, but exceeds the airport noise, takeoff speed and community noise, and landing speed and community noise objectives. The SCAT 15F-B8 and -B9 versions with the General Electric and Pratt & Whitney engines, respectively, are sized to meet all requirements except takeoff and landing speeds and takeoff airport noise. The increased gross weights cause a significant increase in D.O.C. as compared to the SCAT 15F-B7.

The SCAT 15F airframe is feasible to manufacture. The SCAT 15F-B7 has an estimated price of $22.2 million including the price of the General Electric engines but excluding development costs. This price is consistent with the FAA Phase II-A Economic Ground Rules. The payload-range and economics of the SCAT 15F-B7 are shown (Fig. 2-3) utilizing either the GE4/J5G Turbojet (560 lb/sec size) or the P&W STF 219B, 2200°F Turbofan (600 lb/sec size). As compared to the 707-320B, the direct operating costs are eight percent less with the General Electric engine and four percent higher with the Pratt & Whitney engine.

The initial sizing studies were conducted on the NASA conceived SCAT 15F-220 configuration (SCAT 15F-B2, Fig. 2-1) at a ramp gross weight of 430,000 pounds in order to determine its payload-range capabilities. This configuration did not have a canard or aft tail for longitudinal trim; trim was achieved by the use of up-elevon deflection (reducing lift) for takeoff and landing conditions. The low speed performance of this configuration does not allow the maximum range potential to be realized, while meeting reasonable speeds, field lengths, and noise levels for takeoff and landing operations. The addition of a high-lift canard, for use during takeoff and landing only, increased the low-speed, trimmed lift coefficient approximately sixty percent. At a maximum gross weight of 430,000 pounds (P.L. = 43,000 pounds) the SCAT 15F canard design has a range of approximately 3,000 nautical miles at a takeoff speed of 174 knots with a community noise level of 112 PNdb. Meeting the

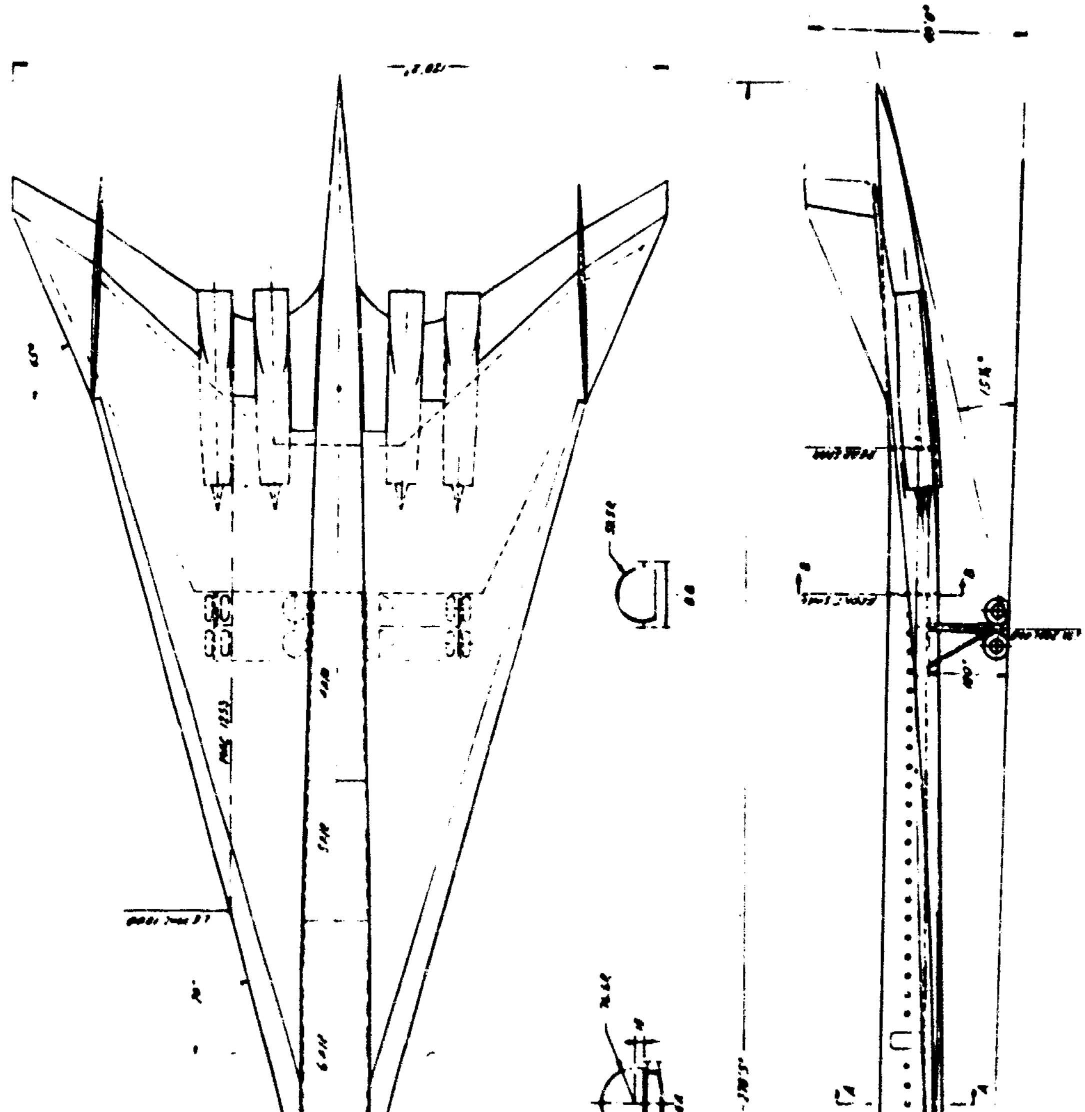


Fig. 2-1 SCAT 15F-B2

Table 2-A Performance Summary Airplane Comparison

MODEL			733-290	SCAT 15F-B7	SCAT 15F-B8	SCAT 15F-B9
Engine Type			GE4/J5G	GE4/J5G	GE4/J5G	P&W STF 219B (2200°F)
Engine Airflow - Lb/Sec			475	560	760	730
Ramp G. Wt. - 1000 Lb			500	500	585	525
Relative D.O.C.			1.000	.98	1.15	1.16
Reserves - Lb			36110	44300	53600	42300
		FAA Objectives				
TAKEOFF	COMMUNITY NOISE - PNdb	105	105	112	105	105
TAKEOFF	AIRPORT NOISE - PNdb	116	116	118	118.8	117.3
TAKEOFF	POWER SETTING	---	MAX. DRY	MAX. AUG.	MAX. AUG.	MAX. AUG.
TAKEOFF	SPEED - KN.	160	160	174	174	174
LANDING	SPEED - KN.	135	125	153	154	151
LANDING	APPROACH NOISE - PNdb	109	111	113	112	116

Note: All airplanes compared at 43000 lb payload (215 passengers), 4000 statute miles range, max. ΔP = 2.3 PSF.

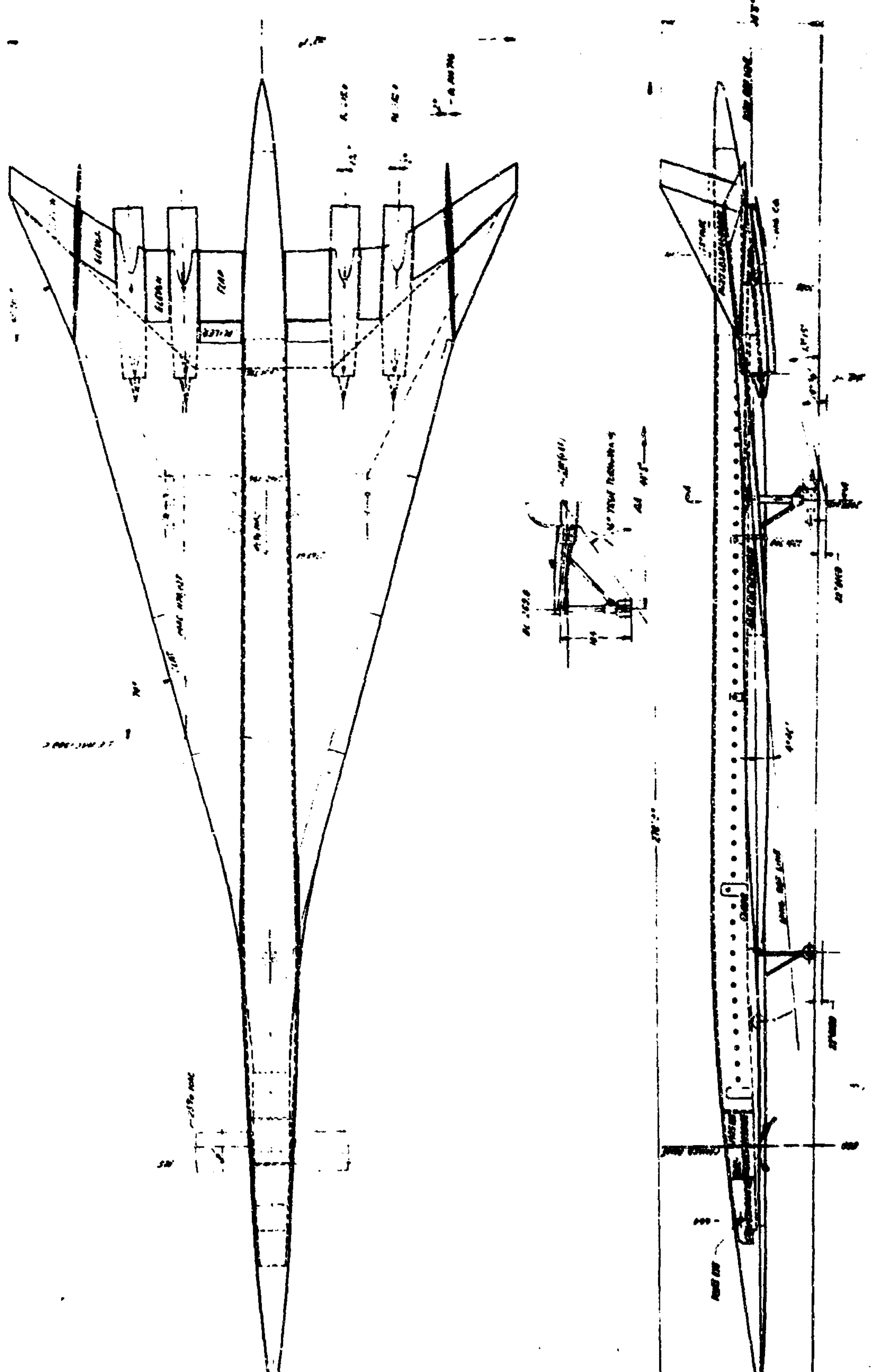


Fig. 2-2 SCAT 15F-87

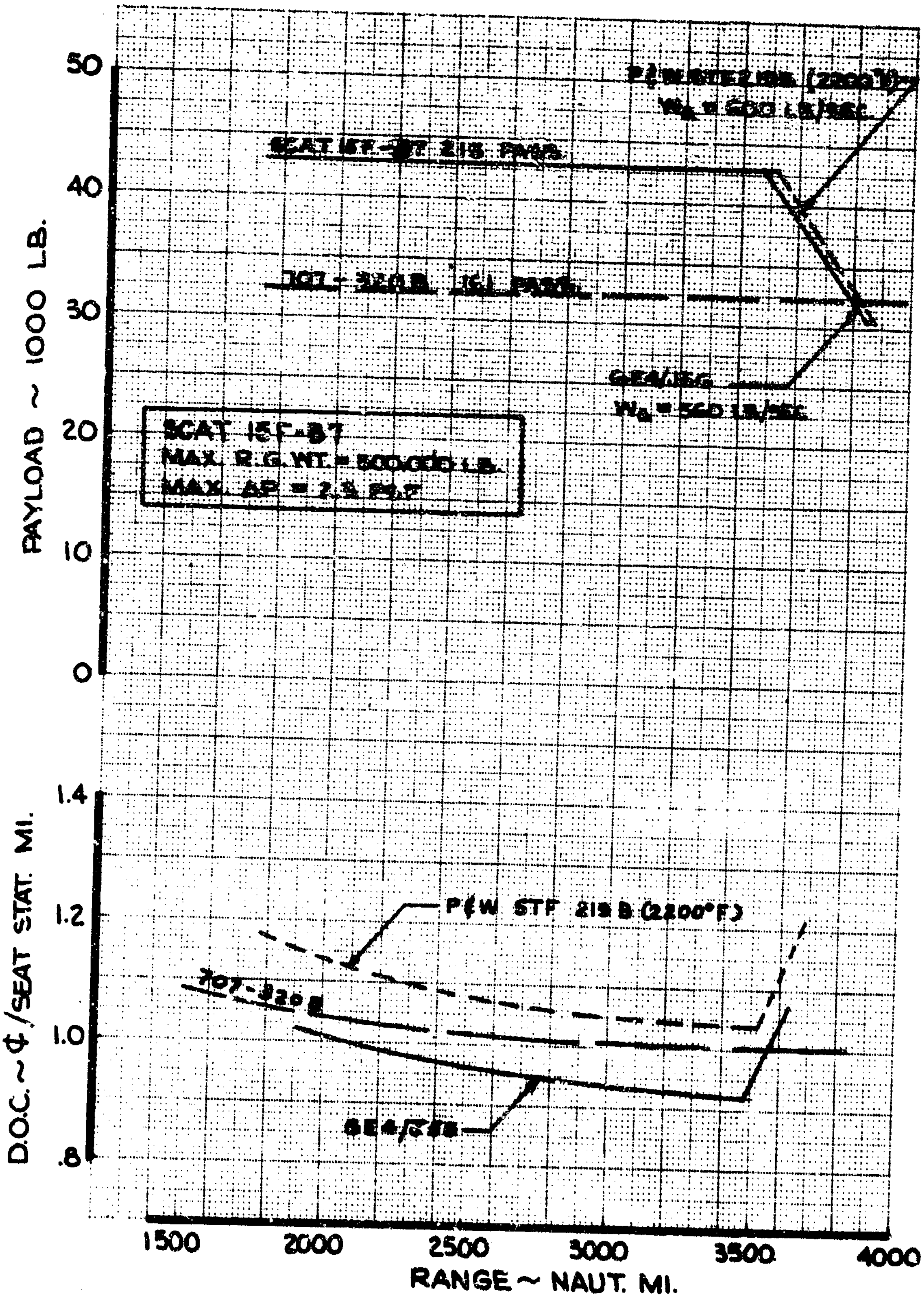


Fig. 2-3 Payload-Range and D.O.C.

Phase II-B design objectives of 160 knots takeoff and 105 PNdb takeoff community noise would result in a range loss of 520 nautical miles. A ramp gross weight of 500,000 pounds was chosen as a reasonable design point to meet the range-payload objective with compromised low-speed performance.

The design overpressure of the SCAT 15F-B7 is 2.3; however, only a forty nautical mile range decrease is incurred at 2.0 psf. Variations in design sonic boom overpressure, (which were computed on the basis of the procedures standardized by FAA for use in Phase II-A) have only a relatively small effect on the range performance of the SCAT 15F-B7 at overpressures above 2.0 psf (Fig. 2-4). High thrust margins and low wing loadings are available during transonic operation and therefore changes in climb schedules have a relatively small effect on climb performance. The high thrust margin is available because the engines and wing area are sized for low speed considerations, resulting in a high thrust to weight ratio (.38 static) and low wing loading.

A ramp wing loading of 62.5 psf was chosen for the SCAT 15F-B7 as a compromise considering range, economics, and low speed performance. The airplane at a gross weight of 500,000 pounds, is sized for a takeoff community noise level of 112 PNdb with a takeoff speed of 174 knots (Fig. 2-5). Decreasing the design takeoff speed from 174 to 160 knots, at a constant 112 PNdb noise level, would result in an eight percent range penalty and a four percent increase in direct operating costs. Meeting the Phase II-B design objectives of 160 knots takeoff speed and 105 PNdb takeoff community noise would further reduce the range to 2900 nautical miles.

The engine cycle comparison in Fig. 2-6 is quite sensitive to the design value for takeoff community noise, with the P&W 2200°F Turbofan superior at the lower noise level because of the lower installed engine weight and fuel reserves. The General Electric engine has been chosen for comparison in the study because of the lower engine price and the later delivery of the P&W 2200°F engine. Table 2-B gives a brief performance summary for the SCAT 15F-B7 for both engine cycles considered in the study. The P&W STF 219B (2200°F) engine has a slight advantage over the GE4/J5G in range (40 nautical miles), airport noise, and approach speed, but would have approximately thirteen percent greater direct operating costs.

The SCAT 15F weights are based on the 733-290 weight substantiation report with due allowances for differences in configuration including the airloads analyses for flexible structure. Fig. 2-7 presents a comparative weight breakdown.

Longitudinal stability and control characteristics appear to present no insurmountable problems. NASA data indicate that satisfactory pitching moment characteristics can be provided throughout the flight envelope, and a satisfactory longitudinal balance is attained with a center-of-gravity range from 37 percent to 46 percent MAC.

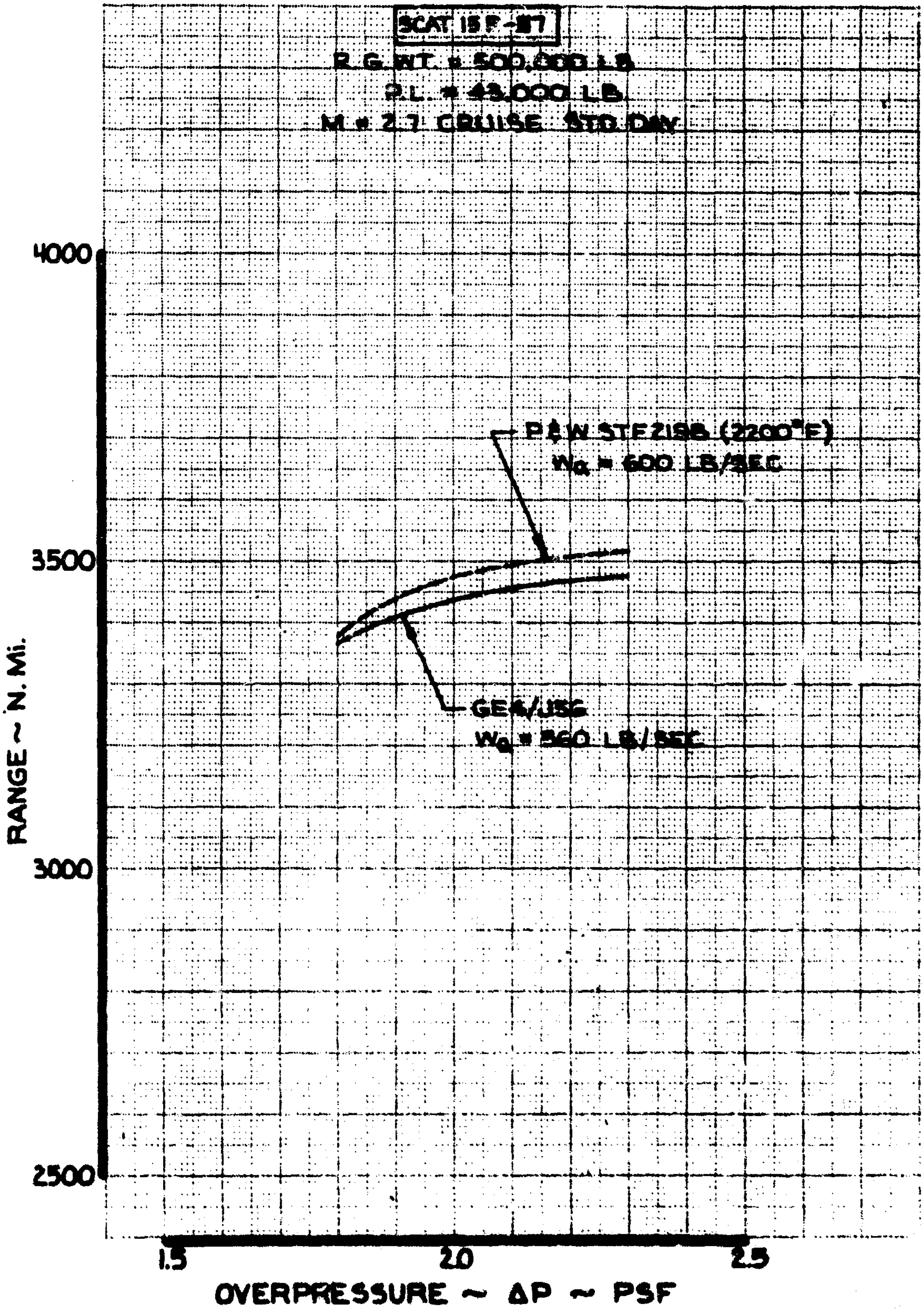


Fig. 2-4. Effect of Overpressure on Range

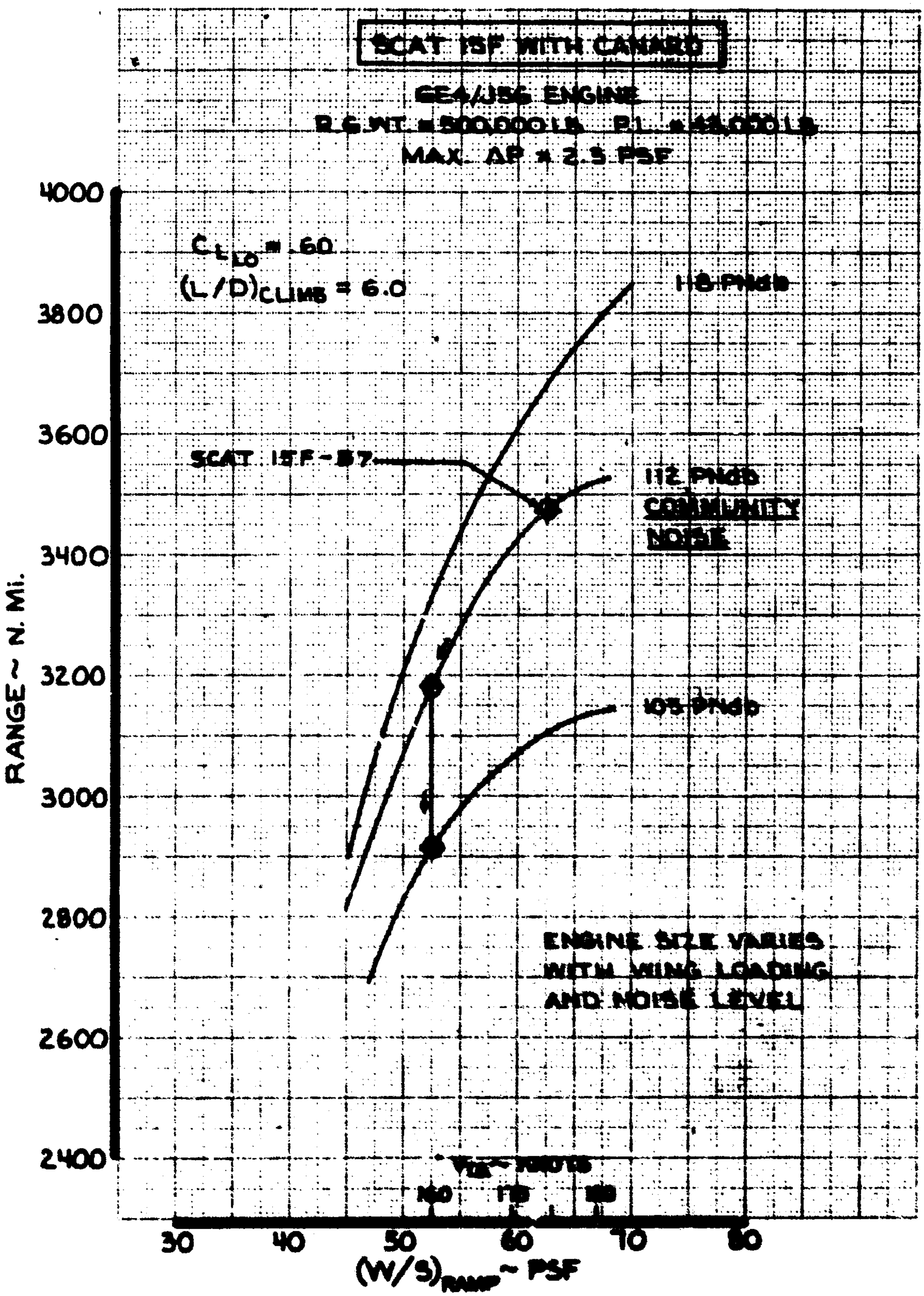


Fig. 2-5 Effect of Wing Loading and Community Noise

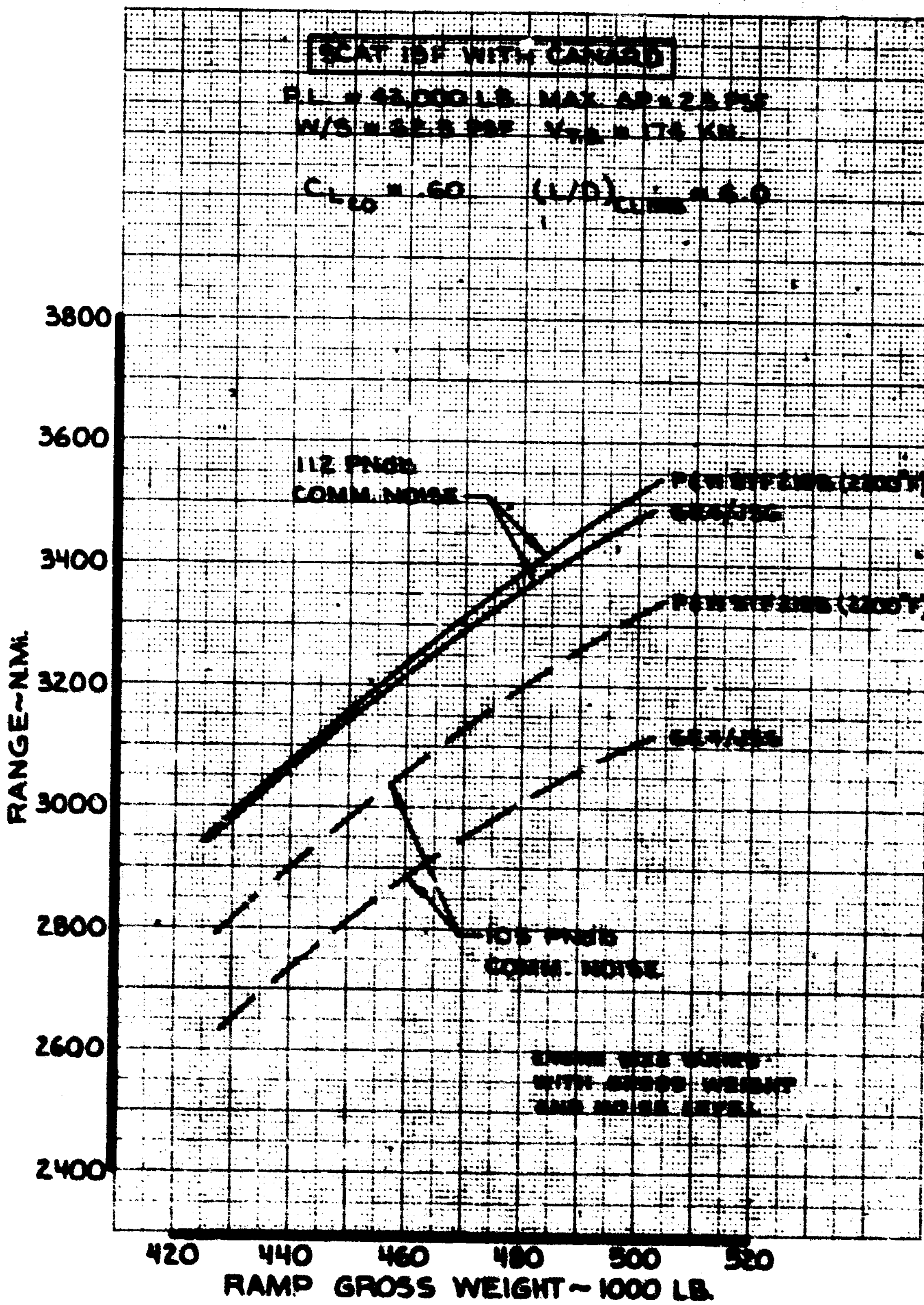


Fig. 2-6 Engine Comparisons

Table 2-B Performance Summary Engine Comparison

ENGINE		GE4/J5G	P&W STF 219B (2200°F)
Ramp Gross Weight - lbs		500,000	500,000
Nominal Payload - lbs		43,000	43,000
Range (Supersonic Mission) N. Mi.		3,476	3,518
OEW - lbs		230,500	224,300
Space Limited Payload - lbs		52,200	52,200
Direct Operating Cost - ¢/S.S.Mi.		0.92	1.04
Thrust Margin, Transonic	$(\frac{T-D}{D})_{min.}$ Std. Day	1.00	.872
Sonic Boom Overpressure P.S.F.	Climb Max.	2.3	2.3
	Initial Cruise	1.43	1.41
	Descent	1.5	1.5
Reserves (lbs)	5% Block Time	7,600	8,100
	20 min. hold, 15000 ft	12,000	9,400
	Missed Approach	5,700	4,000
	Cruise to Alternate	19,000	17,600
	Total	44,300	39,100
Takeoff Performance Sea Level, Standard Day	CAR Takeoff F.L. - ft	6,500	6,100
	Power Setting	Max. Aug.	Max. Aug.
	Community Noise - PNdb	112	112
	Airport Noise - PNdb	118	116.7
	Speed - Knots	174	174
Landing Performance Sea Level Std. Day	Normal weight - lbs	317,800	306,400
	Approach speed - knots	153	150
	Approach noise - PNdb	113	116.5
	CAR F.L. - ft	7,200	7,000

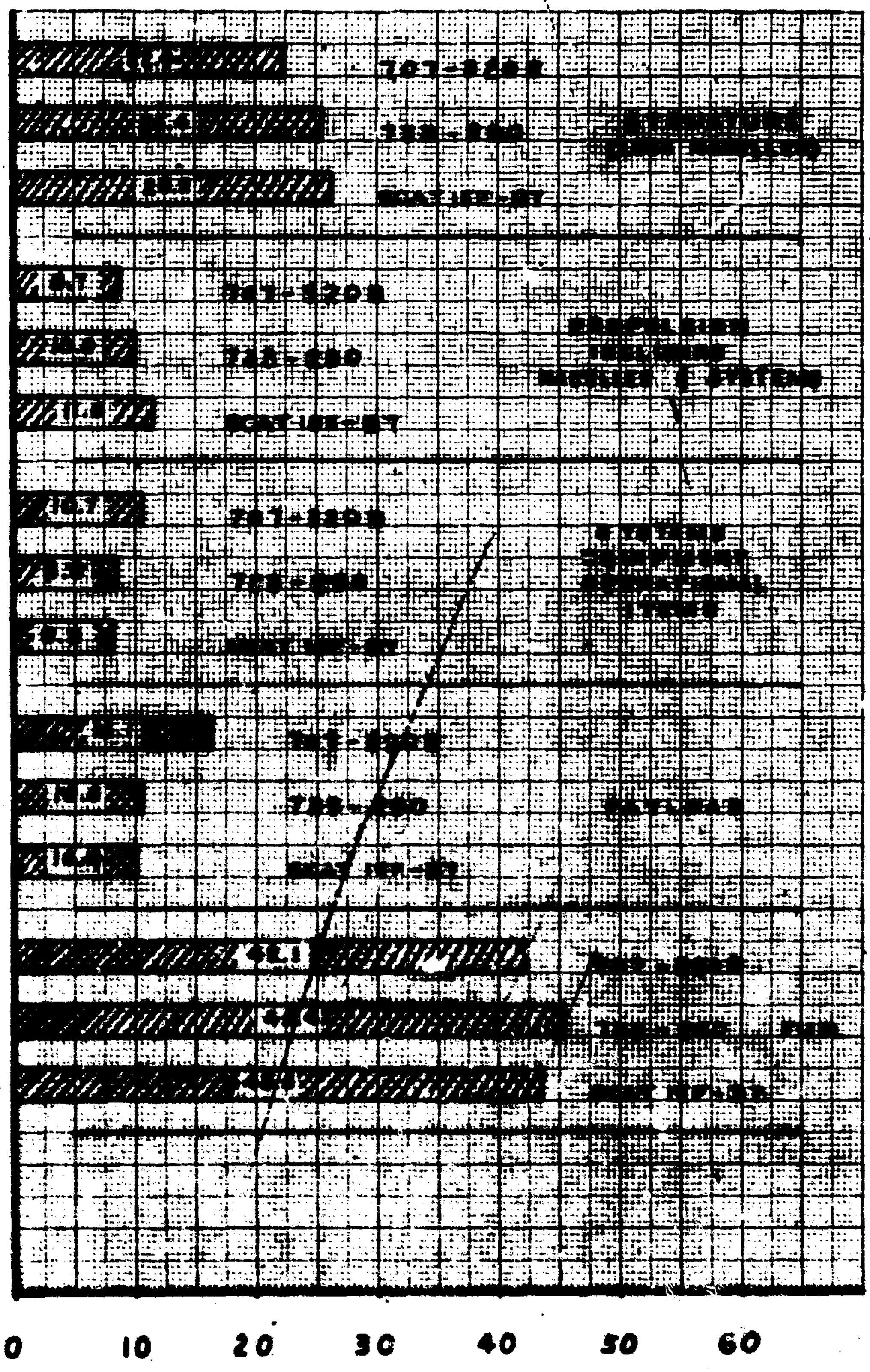


Fig. 2-7 Weight comparison

Lateral-directional stability and control analyses have been restricted for the most part to the critical low-speed regime. Lateral control appears to be inadequate to handle 90 degree crosswinds in excess of 13 knots at the design 153 knot landing approach speed. This results primarily from the large dihedral effect ($C_{\ell\beta}$) of this highly-swept configuration. The capability to land in 90 degree, 30 knot crosswinds has been provided with the incorporation of a crosswind landing gear which eliminates the need for a "decrab" maneuver and the associated large lateral control requirements. Detailed study would be required to ascertain the capability to operate in gusty air with the present control layout and division of authority between the lateral and longitudinal controls.

Satisfactory directional stability is inherent in this outboard-tail configuration at all Mach numbers and airplane attitudes within the operating flight envelope. The vertical tail areas have been increased and planform changed somewhat from that of the NASA SCAT 15F model to provide adequate rudder control for the critical engine failure condition at takeoff.

Analyses of the lateral-directional dynamic stability at low-speed and supersonic cruise have shown poor Dutch roll characteristics. It is probable that a triplicated yaw damper system will be required to ensure acceptable handling qualities at all flight conditions, and to eliminate the necessity of aborting a flight when a single yaw damper failure occurs sometime after takeoff.

3.0 AERODYNAMICS

Studies have been conducted to determine the effect of variation in gross weight, wing loading, engine size, overpressure, and takeoff and landing characteristics in order to determine the feasibility of the SCAT 15F concept for use in the design of a safe, economical supersonic transport. These studies have been based on the FAA Phase II-B design objectives.

Two engine cycles have been considered, i.e. the GE4/J5G turbojet and the P&W STF 219B (2200°F) turbofan. The installation engine data are as presented in the Phase II-A Proposal, D6-8680-8, Aircraft Propulsion System. A cruise Mach number of 2.7 was used for all studies with a nominal payload of 43,000 pounds (215 passengers, 90 percent tourist, 10 percent first-class, on FAA Economic Intercontinental Rules). Trades are presented to show the effect of operating empty weight, lift-drag ratio, design range, low speed performance, and noise levels.

3.1 DESIGN OBJECTIVES

During the SCAT 15F feasibility study, the effect of meeting the Phase II-A and II-B design objectives were investigated. These objectives were used as guidelines, and deviations from them are discussed in this report. A summary of the FAA II-B performance design objectives are as follows:

3.1.1 Speed

A cruise speed capability of at least Mach 2.5.

3.1.2 Range and Payload

A minimum payload of 30,000 pounds at a range of 4000 statute miles.

3.1.3 Sonic Boom Overpressures

Initial cruise 1.5 PSF
Transonic acceleration - 2.0 PSF

3.1.4 Takeoff

Maximum community noise level of 105 PNdb at a point three miles from initiation of takeoff roll. Sea Level standard day.

Maximum airport noise level of 116 PNdb, 1500 feet from centerline of runway. Sea Level standard day.

The airplane should be capable of taking off from a 10,500 foot runway at maximum design takeoff gross weight in an ISA + 15°C hot day atmosphere at sea level. At maximum gross takeoff weights the lift-off speed should not exceed 160 knots (EAS).

The aircraft should have the ability to takeoff in 30 knots, 90 degree crosswinds.

3.1.5 Landing

Maximum approach noise of 109 PNdb at a point one mile from runway threshold.

The required runway length should not exceed 8000 feet under wet runway conditions with the aircraft at the maximum authorized landing weight.

The maximum acceptable boundary speed should be 135 knots (EAS).

The aircraft should have the ability to land in 30 knots, 90 degree crosswinds.

3.2 AIRPLANE PERFORMANCE

3.2.1 Engine-Airframe Matching

Initial sizing studies were conducted on the NASA SCAT 15F-220 planform at a ramp gross weight of 430,000 pounds. Based on NASA wind tunnel data, the low speed analysis (Par. 3.3.2.2) resulted in a takeoff lift coefficient of 0.385, second segment climb lift-drag ratio of 6.8, and approach lift coefficient of 0.30. This configuration was trimmed by trailing edge surfaces which decrease wing lift at a given attitude. Very low wing loadings are necessary for reasonable low speed performance. The engine-airframe sizing characteristics are shown in Fig. 3-1 for the GE4/J5G turbojet. The airplane has a high aerodynamic efficiency as evidenced by the range capability of greater than 3500 nautical miles at a wing area of about 6000 square feet. However, the serious compromise required by low speed performance is indicated by the need for a wing area of greater than 9000 square feet to achieve a takeoff speed of 190 knots, with a corresponding range of less than 2800 nautical miles. Table 3-A shows a comparison between the GE4/J5G and P&W STF 219B (2200°F) engines when the SCAT 15F-220 planform is sized for a takeoff speed of 190 knots. The data for airplanes matched to achieve two community noise levels are also shown. If the design noise level is relaxed to 112 PNdb, the configuration has a range of approximately 2740 nautical miles at a ramp gross weight of 430,000 pounds. Approach speeds would be on the order of 175 to 177 knots.

In an effort to improve the match between low speed and supersonic cruise performance, the use of a high lift canard was studied on the SCAT 15F-220 planform. The canard, which is used for takeoff and landing only, increases the takeoff trimmed lift coefficient from 0.385 to 0.60. Higher lift coefficients are possible; however, the loss in second segment climb lift-drag ratio adversely affects the overall sizing of the configuration. This is discussed further in Par. 3.2.3, Trade Studies. By use of the canard, the approach lift coefficient increases from 0.30 to 0.50. The sizing characteristics of the SCAT 15F-220 canard design are shown in Figs. 3-2 and 3-3 for ramp gross weights of 430,000 pounds and 500,000 pounds, respectively, with the GE4/J5G turbojet. The engine airframe match of the final configuration of SCAT 15F-B7 is shown in Fig. 3-3. Similar data are shown in Fig. 3-4 for the P&W STF

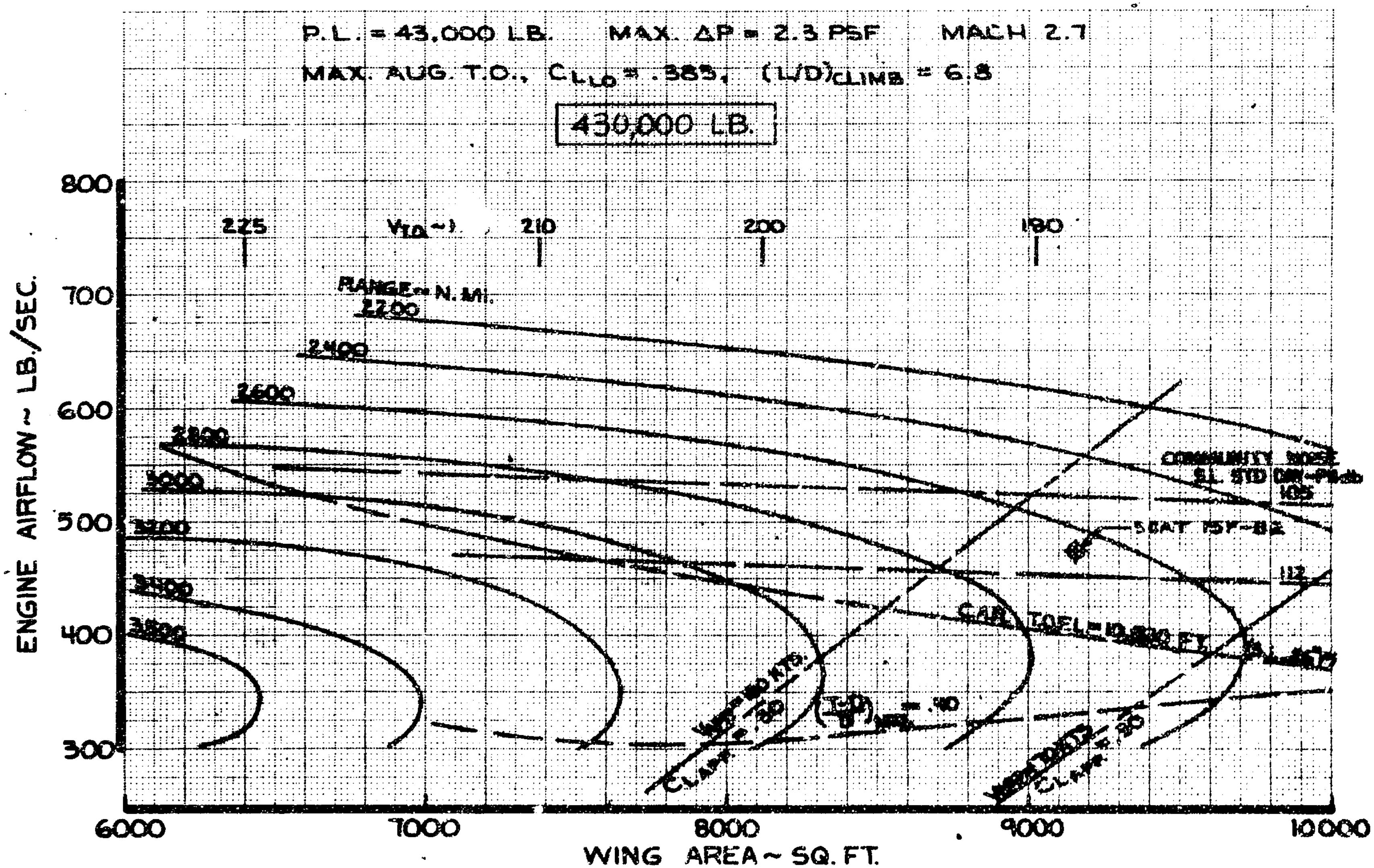


Fig. 3-1 Engine-Airframe Sizing - GE4/J5G Engine SCAT 15F No Canard, R. G. Wt. = 430,000 Lb.

Table 3-A Enging Sizing Comparison SCAT 15F No Canard, R. G. Wt. = 430,000 Lb.

WING LOADING = 47.6 PSF P. L. = 43,000 LB. MAX. ΔP = 2.3 PSF $C_{L_{LO}} = .385$, $(L/D)_{CLIMB} = 6.8$, $C_{L_{APP}} = .30$			GE 4/J5G ENGINE	P & W STF 219B (2200° F) ENGINE
$V_{T.O.}$ = 190 KN. COMMUNITY NOISE = 105 PNdb T.O.F.L. < 10,500 FT. (S.L., 86° F)	WING AREA	(FT.^{2})	9030	9030
	ENGINE AIRFLOW	(LB./SEC.)	525	560
	AIRPORT NOISE	(PNdb)	117.7	116.5
	APPROACH SPEED	(KN.)	180	177
	RANGE	(N. Mi.)	2550	2650
$V_{T.O.}$ = 190 KN. COMMUNITY NOISE = 112 PNdb T.O.F.L. < 10,500 FT. (S.L., 86° F)	WING AREA	(FT.^{2})	9030	9030
	ENGINE AIRFLOW	(LB./SEC.)	455	485
	AIRPORT NOISE	(PNdb)	117.3	115.5
	APPROACH SPEED	(KN.)	177	175
	RANGE	(N. Mi.)	2740	2730

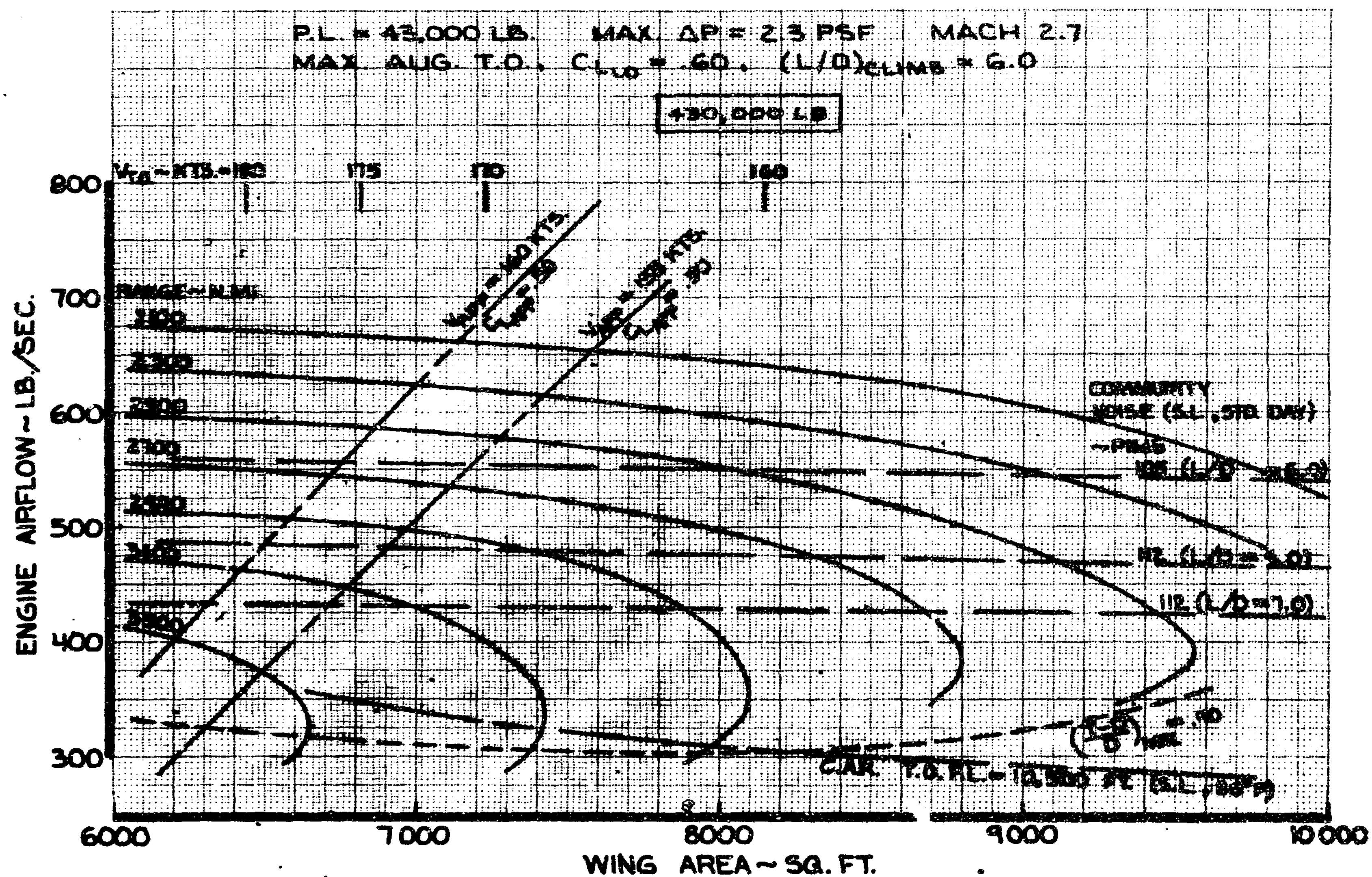


Fig. 3-2 Engine-Airframe Sizing - GE4/J5G Engine SCAT 15F with Canard, R. G. Wt. = 430,000 Lb.

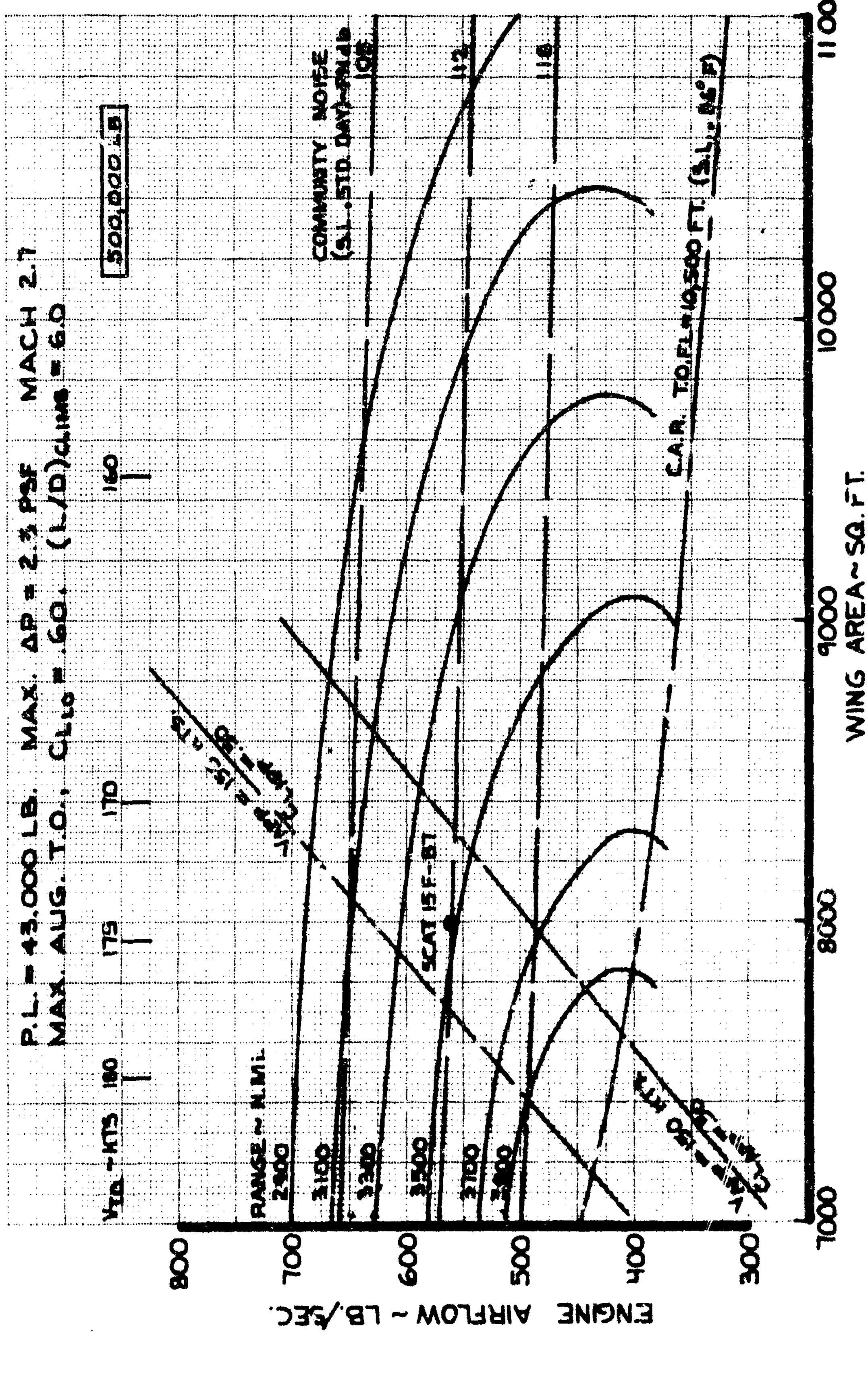


Fig. 3.3 Engine-Airframe Sizing - GE4/J5G Engine SCAT 15F with Canard, R. G. Wt. = 500,000 Lb.

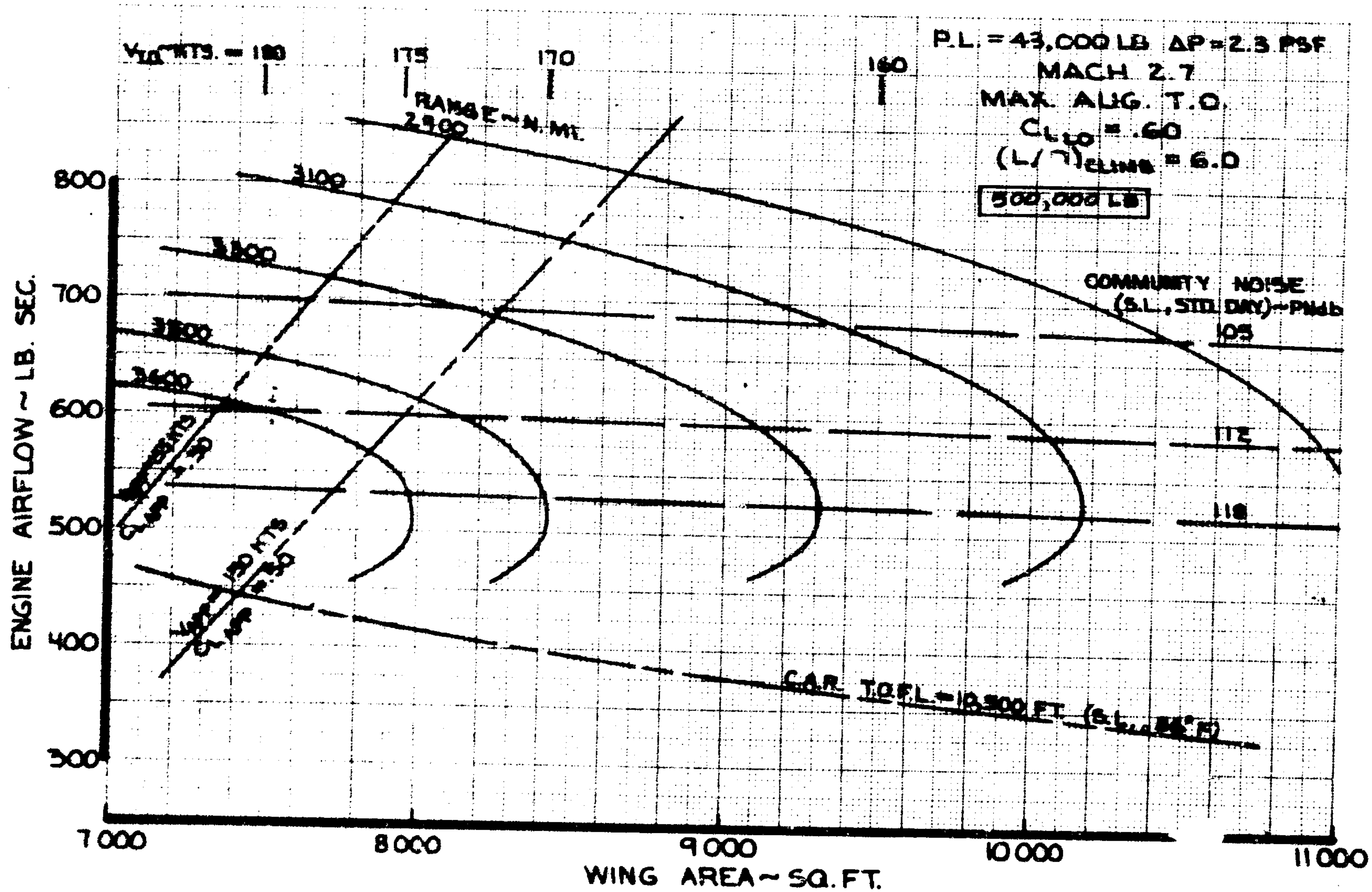


Fig. 3-4 Engine-Airframe Sizing - P&W STF219B (2200°F) Engine SCAT 15F with Canard, R. G. Wt. = 500,000 Lb.

219B 2200° F) turbofan at a ramp gross weight of 500,000 pounds. It is noted that the use of a canard (improved low speed performance) allows the configuration to be sized nearer to the maximum range potential at a given gross weight. The weight penalty associated with the canard has been included in these data. The wing loading is determined by takeoff and approach speeds while the engine is sized by the community noise level. Field lengths and transonic accelerations are not critical.

The engine-airframe matching of the SCAT 15F-220 canard design is summarized in Tables 3-B and 3-C for gross weights of 430,000 and 500,000 pounds, respectively. Performance with the two engine cycles (GE4/J5G vs. P&W STF 219B, 2200°F) are compared at a wing loading of 62.5 PSF for community noise levels of 105 PNdb and 112 PNdb. When sizing for a noise level of 112 PNdb the P&W STF 219B has a small advantage at the higher gross weights in terms of range (+40 nautical miles), airport noise, and approach speed, but would have greater direct operating costs of approximately 13 percent. However, the P&W STF 219B engine has approximately a 200 nautical mile range advantage over the GE 4/J5G when sizing for a community noise level of 105 PNdb.

3.2.2 SCAT 15F-B7 Performance

The performance of the SCAT 15F-B7 is summarized in Figs. 3-5 through 3-12. The performance is computed in accordance with the FAA Phase II-B rules and meeting the certification requirements of CAR SR422B.

Figure	
3-5	Supersonic Cruise Profile, Basic Mission
3-6	Speed-Altitude Schedule
3-7	Cruise Range vs. Gross Weight
3-8	Takeoff Field Length
3-9	Takeoff Speed
3-10	Takeoff Community Noise
3-11	Landing Field Length
3-12	Approach Speed

3.2.3 Trade Studies

The following paragraphs present performance trade data for the SCAT 15F canard design.

Figure 3-13 shows design range as a function of takeoff lift coefficient and second segment climb lift-drag ratio. Data are shown for the GE4/J5G engine at a ramp gross weight of 500,000 pounds. The curve marked "available low speed performance" is estimated to be the best performance available for the SCAT 15F-B7 configurations. Maximum range occurs at a takeoff lift coefficient of 0.60. These data are for matched airplanes, varying engine airflow, and wing loading, sized for a constant takeoff speed and community noise level. If the takeoff lift coefficient could be increased to 0.70 and lift-drag ratio increased to 7.0, the range increase would be approximately 350 natucial miles, holding the 174 knot takeoff speed and 112 PNdb noise level. If this low speed performance level could be attained (0.70 $C_{L_{LO}}$ and 7.0 L/D), the SCAT 15F-B7 configuration, as sized, would meet all of the Phase

Table 3-B Engine Sizing Comparison SCAT 15F with Canard, R. G. Wt. = 430,000 Lb.

WING LOADING = 62.5 PSF P.L. = 43,000 LB. MAX. ΔP = 2.3 PSF $C_{L_{LO}}$ = .60, $(L/D)_{CLIMB}$ = 6.0, $C_{L_{APP.}}$ = .50			GE 4/J5G ENGINE	P&W STF 219B (2200° F) ENGINE
$V_{T.O.}$ = 174 KN. COMMUNITY NOISE = 105 PNdb T.O.F.L. < 10,500 FT. (S.L., 86° F)	WING AREA	(FT^2)	6880	6880
	ENGINE AIRFLOW	(LB./SEC.)	555	595
	AIRPORT NOISE	(PNdb)	118	116.7
	APPROACH SPEED	(KN.)	159	156
	RANGE	(N. Mi.)	2655	2815
$V_{T.O.}$ = 174 KN. COMMUNITY NOISE = 112 PNdb T.O.F.L. < 10,500 FT. (S.L., 86° F)	WING AREA	(FT^2)	6880	6880
	ENGINE AIRFLOW	(LB./SEC.)	480	515
	AIRPORT NOISE	(PNdb)	117.7	115.8
	APPROACH SPEED	(KN.)	156	154
	RANGE	(N. Mi.)	2985	2985

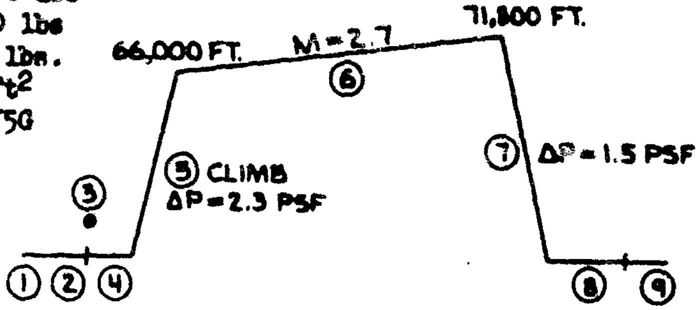
Table 3-C Engine Sizing Comparison SCAT 15F with Canard, R. G. Wt. = 500,000 Lb.

WING LOADING = 62.5 PSF
P.L. = 43,000 LB. MAX. ΔP = 2.3 PSF
$C_{L_{LO}} = .60$, $(L/D)_{CLIMB} = 6.0$, $C_{L_{APP}} = .50$

Conditions	Parameter	Units	GE 4/J5G ENGINE	P&W STF 219B (2200°F) ENGINE
$V_{T.O.}$ = 174 KN.	WING AREA	(FT.^{2})	8000	8000
COMMUNITY NOISE = 105 PNdb	ENGINE AIRFLOW	(LB./SEC.)	650	695
T.O.F.L. < 10,500 FT. (S.L., 86°F)	AIRPORT NOISE	(PNdb)	118.3	117.5
	APPROACH SPEED	(KN.)	156	152
	RANGE	(N. Mi.)	3100	3320
$V_{T.O.}$ = 174 KN.	WING AREA	(FT.^{2})	8000	8000
COMMUNITY NOISE = 112 PNdb	ENGINE AIRFLOW	(LB./SEC.)	560	600
T.O.F.L. < 10,500 FT. (S.L., 86° F)	AIRPORT NOISE	(PNdb)	118	116.7
	APPROACH SPEED	(KN.)	153	150
	RANGE	(N. Mi.)	3476	3518
	D.O.C.	(¢/S.S. Mi.)	.92	1.04

SCAT 15F-B7

Ramp G. Wt. = 500,000 lbs
OWE = 230500 lbs
Payload = 43000 lbs.
Wing Area = 8000 Ft^2
Engine = GE 4/J5G
Wa = 560 lb/sec
Std. Day, Zero Wind
ΔP_{MAX} = 2.3 PSF
Phase II-A Rules



BLOCK TIME = 2.928 Hrs
BLOCK FUEL = 183900 lbs.

	Fuel Used Lbs.	Fuel Remaining Lbs.	Wt. @ End of Opn Lbs.	Time Hr.	Distance N.Mi.
1. Taxi-out (10 min.)	3920	222580	496080	.167	0
2. Takeoff	2170	220410	493910	.009	0
3. Air Maneuver (250 Kts. EAS @ 5000 ft.)	5860	214550	488050	.083	0
4. S.L. Acceleration	2860	211690	485190	.012	3
5. Climb & Acceleration	43937	167753	441253	.237	183
6. M = 2.7 Cruise Climb	121513	46240	319740	1.99	3086
7. Descent (V_{cruise} to $V_{appr.}$)	1940	44300	317800	.340	204
8. Landing ($V_{appr.}$ to V = 0)	Incl. in 3		317800	.007	0
9. Taxi-in (5 min.)	(1700)*		317800	.083	0
TOTAL MISSION:	182200			2.928	3476

Reserves:

a. 5% Block Time @ end of cruise fuel flow	7600
b. 20 min. hold @ 15000 ft.	12000
c. 8 min. missed approach at 1500 ft.	5700
d. Climb & cruise to altn 300 st. mi., desc. to 15000 ft.	19000
TOTAL RESERVES:	44300
TOTAL FUEL	226500

* Not included in mission fuel.

Fig. 3-5 Supersonic Cruise Flight Profile

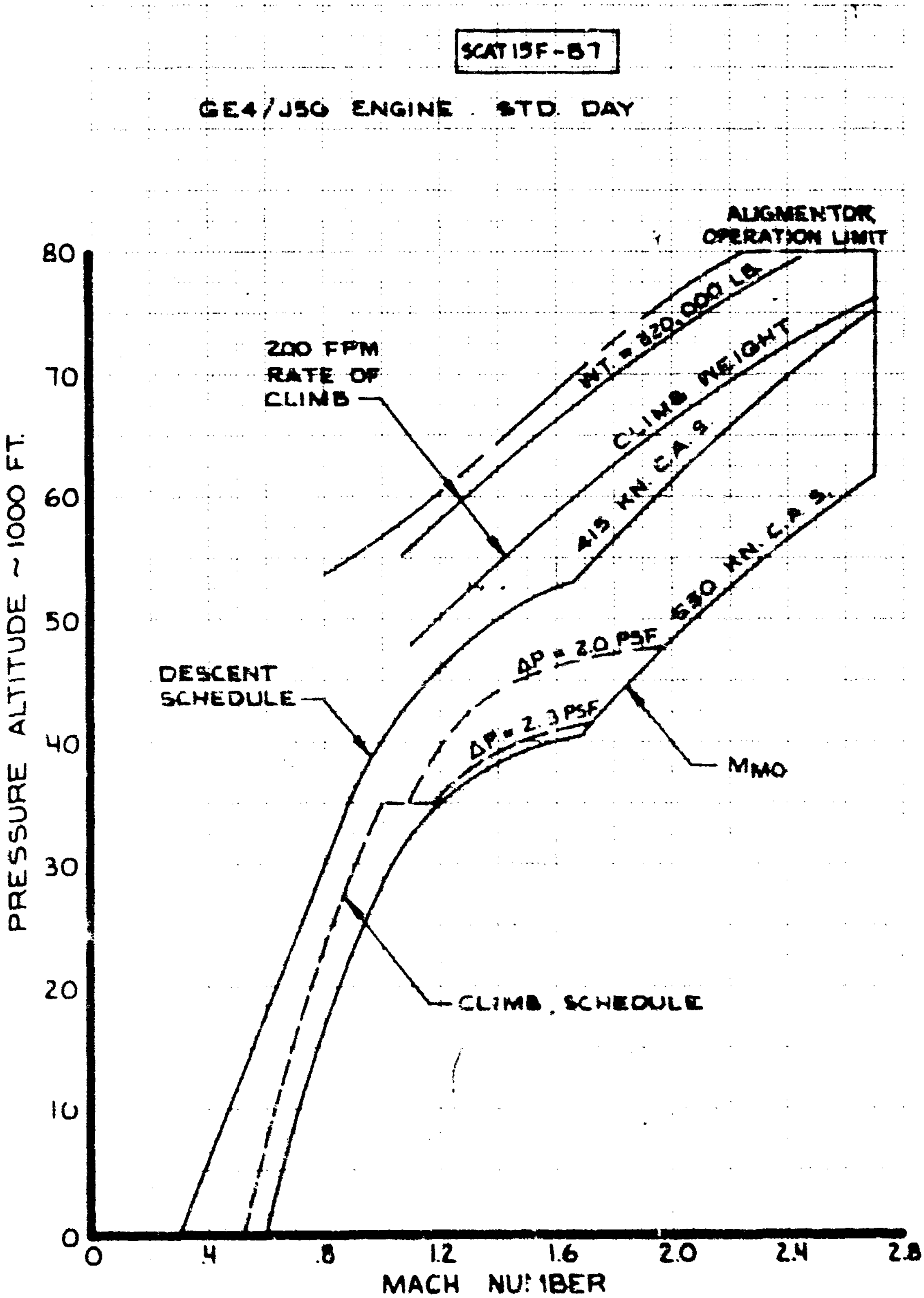


Fig. 3-6 Speed-Altitude Schedule

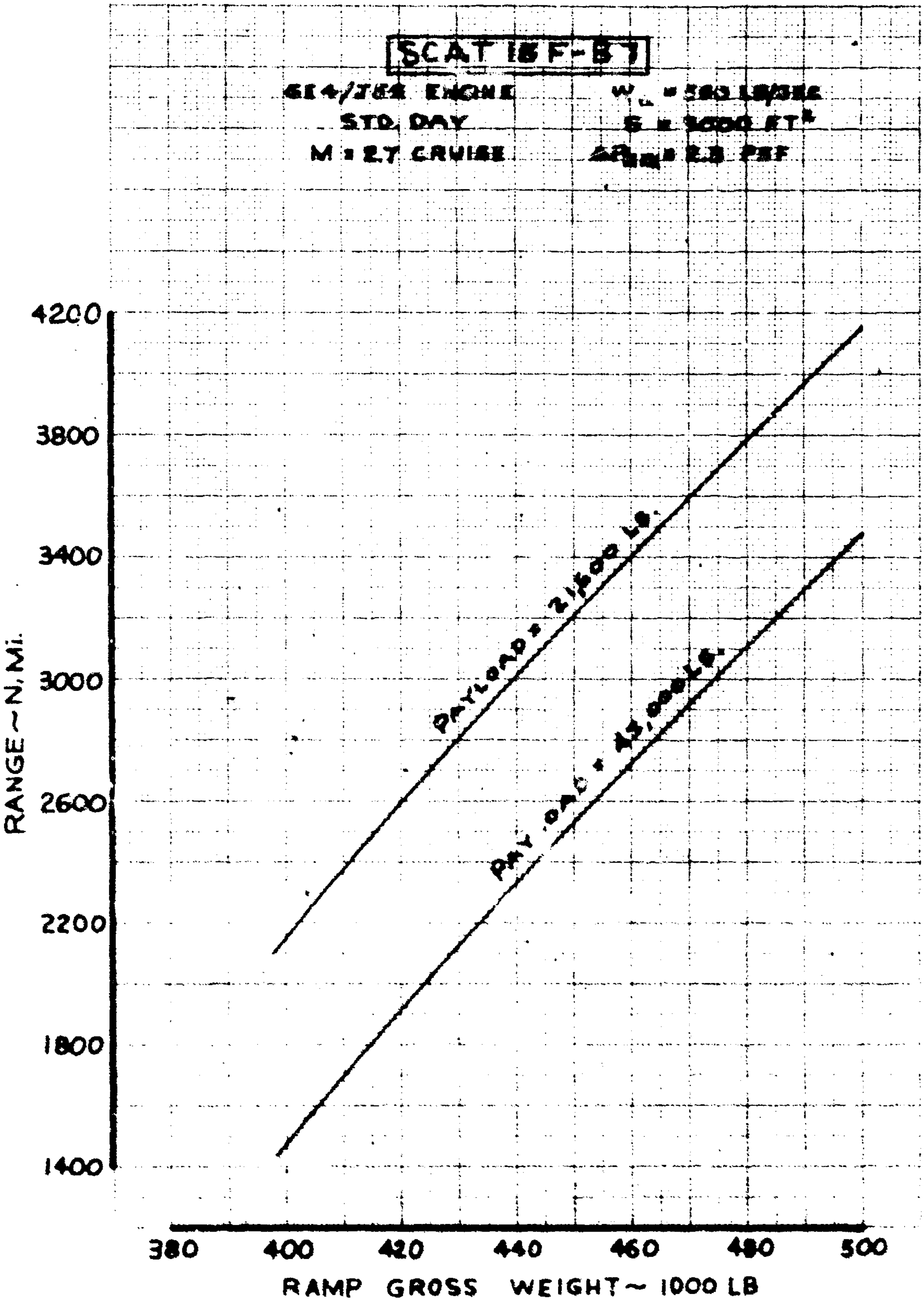


Fig. 3-7 Range Versus Gross Weight

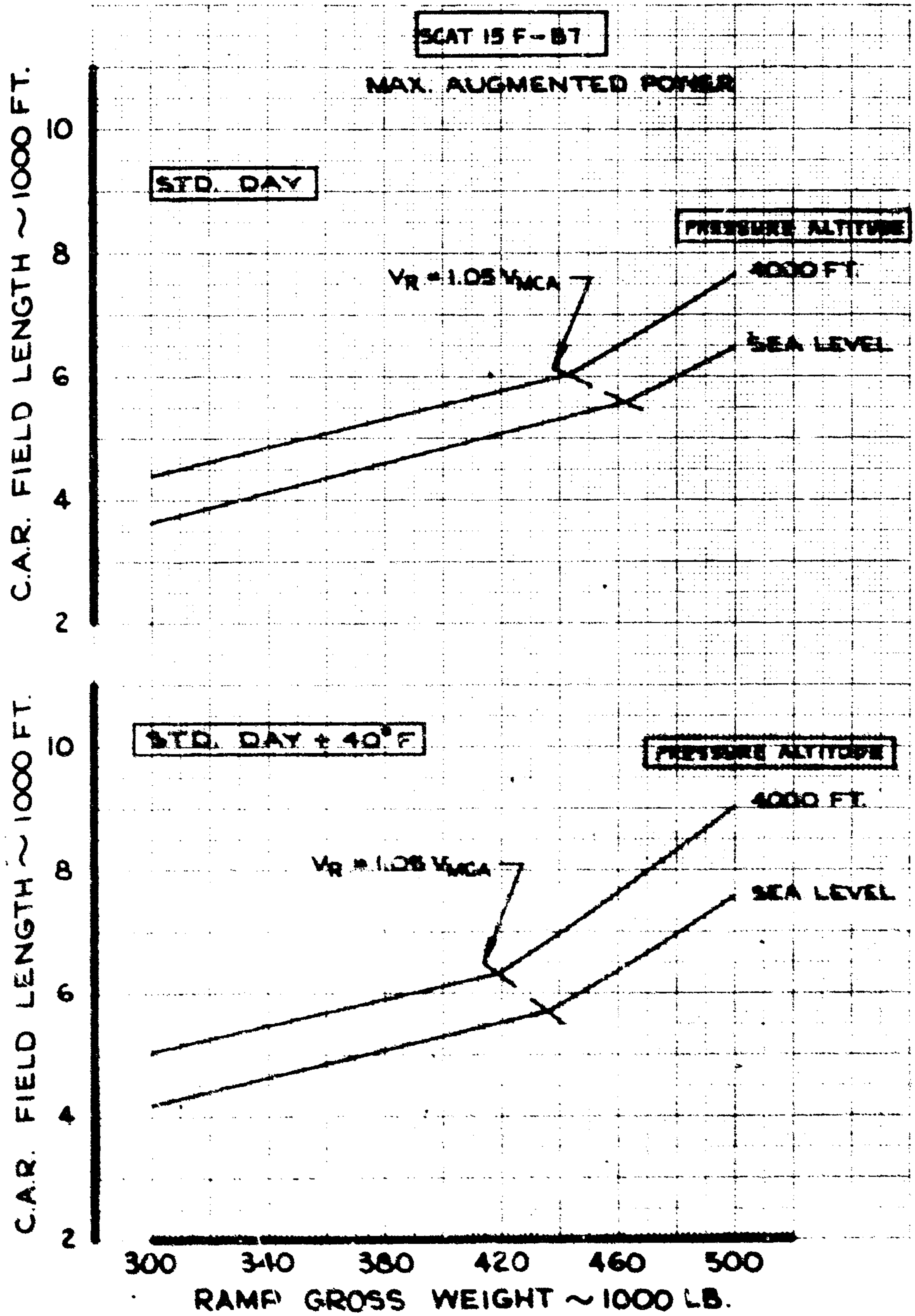


Fig. 3–8 Takeoff Field Length

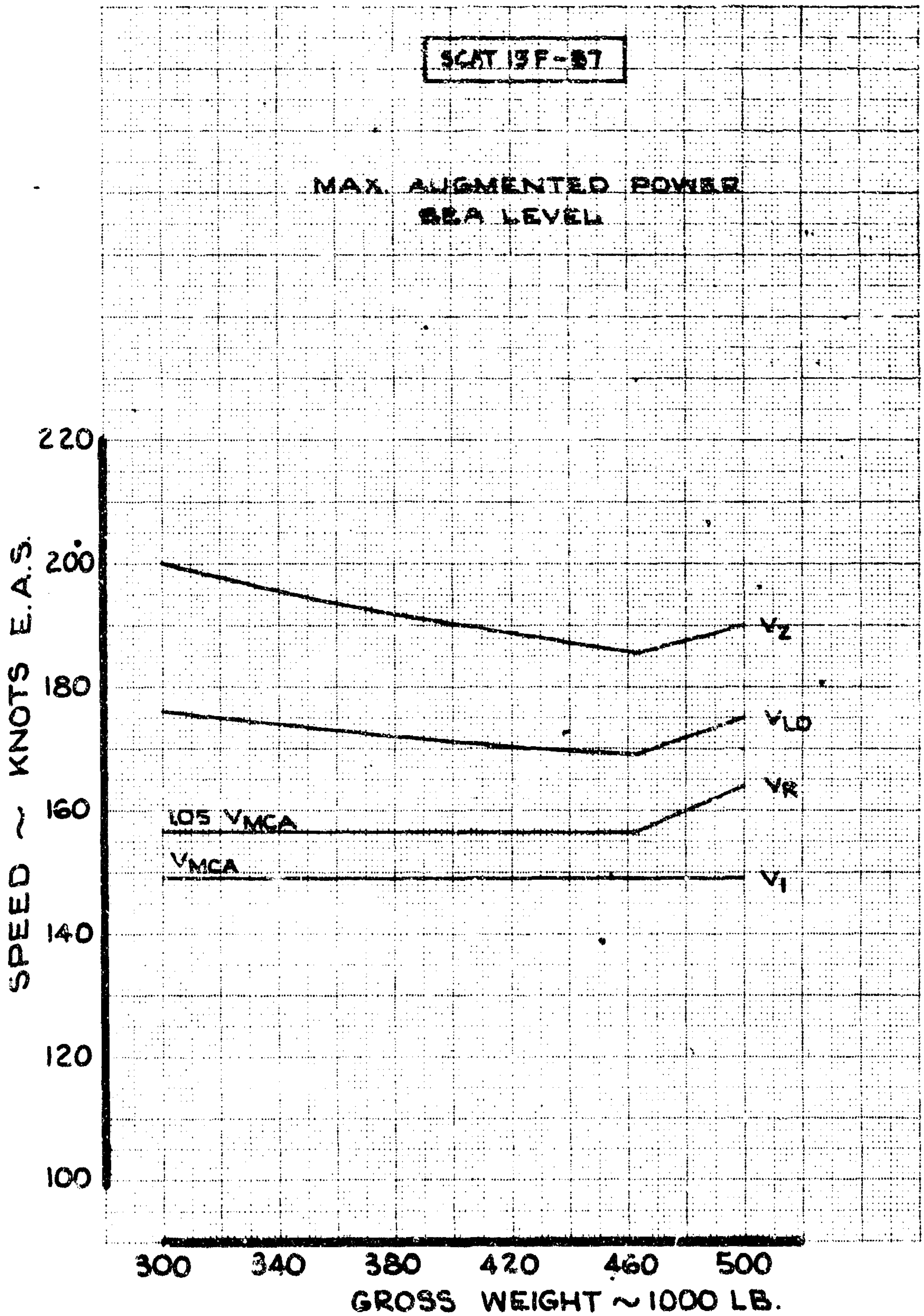


Fig. 3-9 Takeoff Speeds

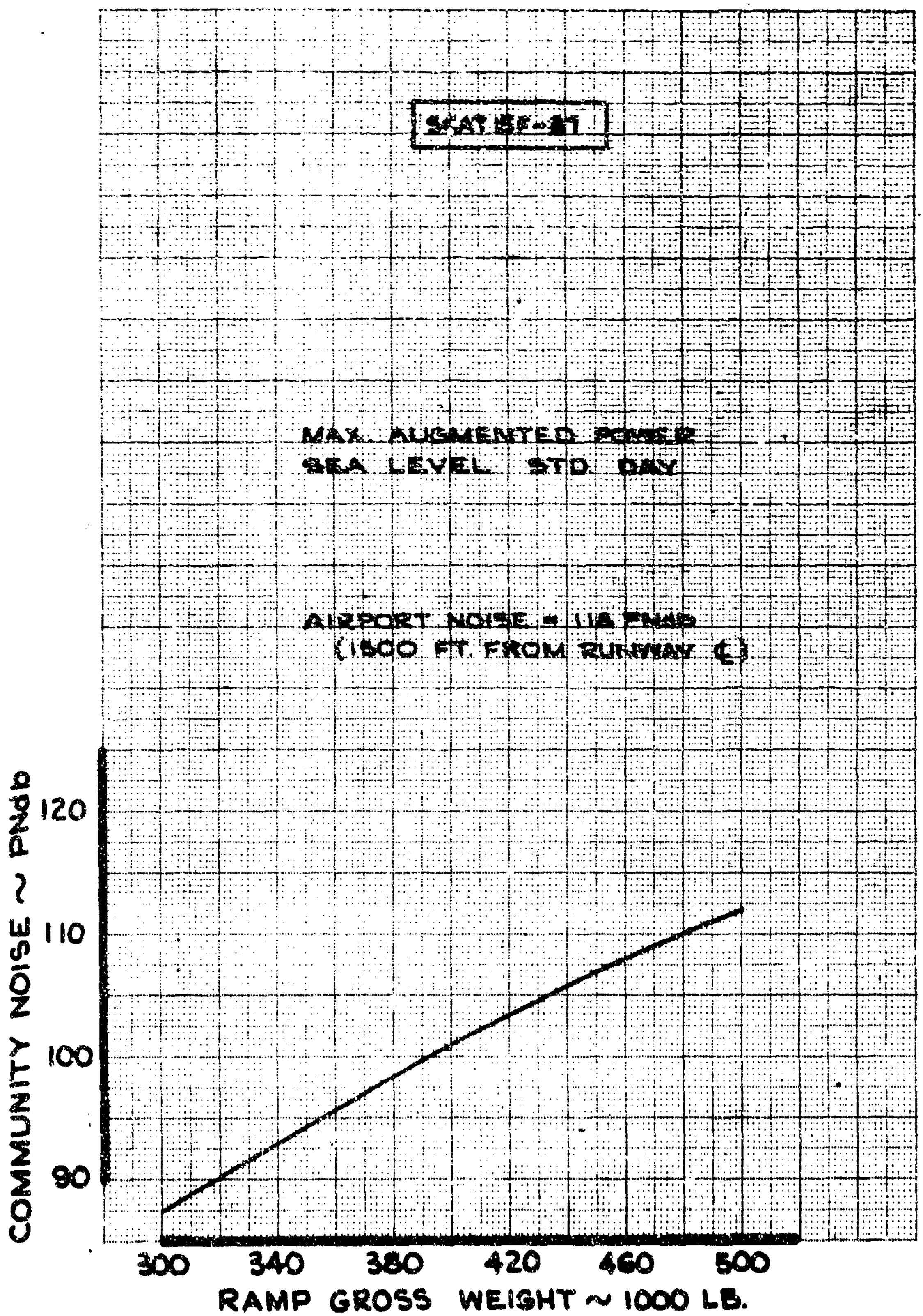


Fig. 3–10 Takeoff Community Noise

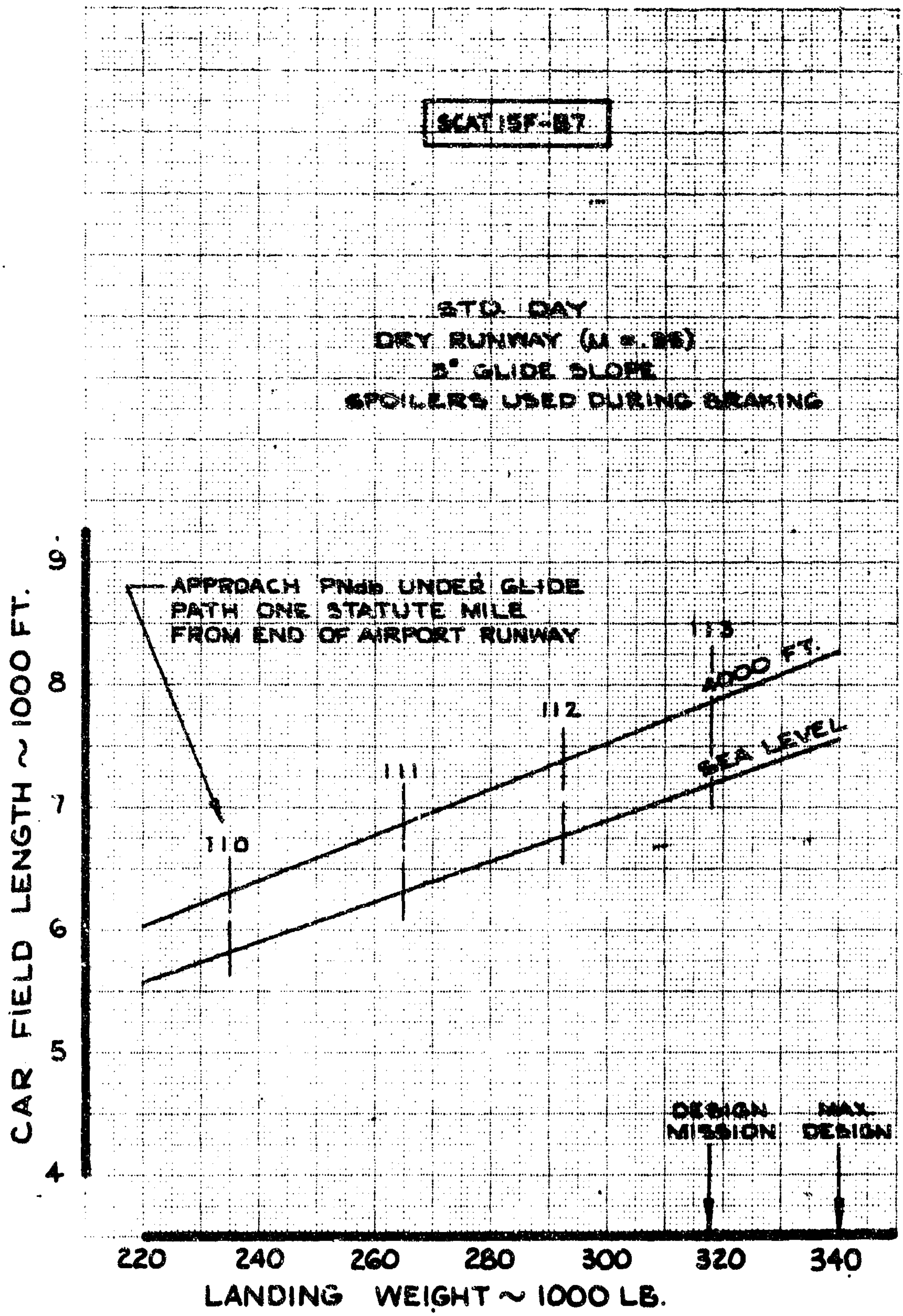


Fig. 3-11 Landing Field Length

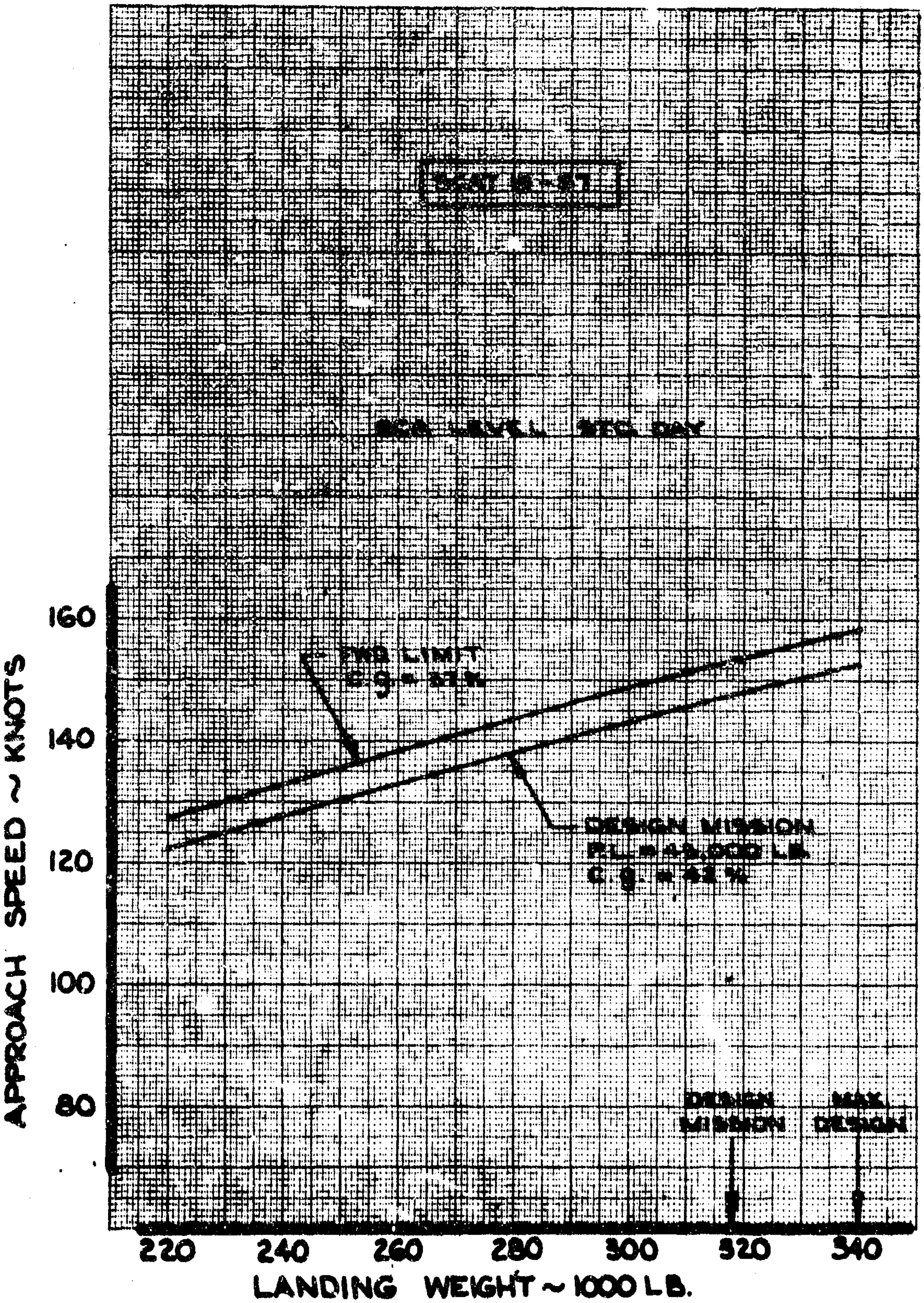


Fig. 3-12 Approach Speeds

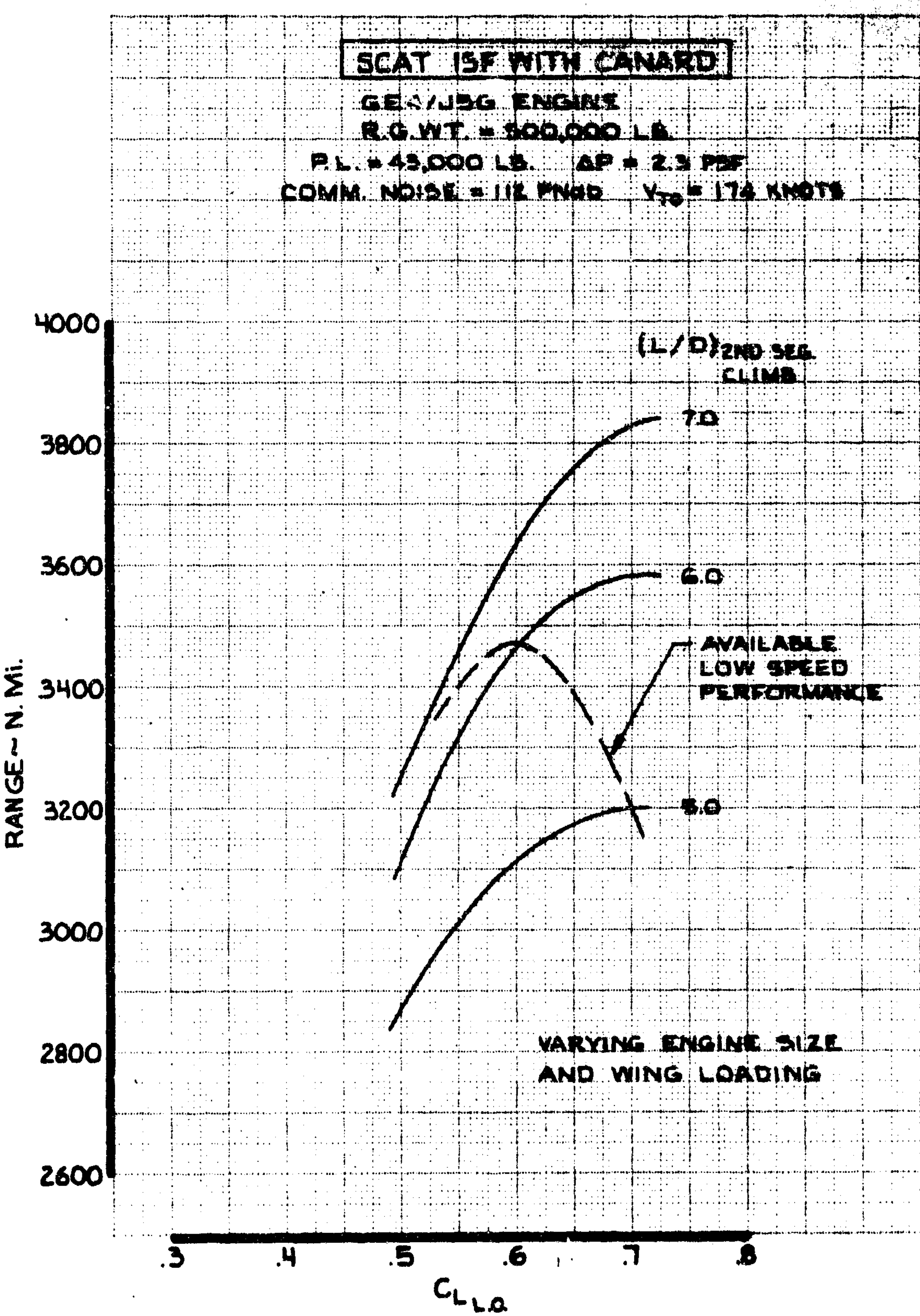


Fig. 3-13 Low Speed Performance Trade

II-B design objectives; i.e., 160 knot takeoff speed, 105 PNdb community noise, and 135 knot approach speed.

The effect of takeoff speed on range as a function of gross weight is shown (Fig. 3-14) for constant community noise levels of 105 PNdb and 112 PNdb. Increasing the takeoff speed from 160 to 175 knots increases the range 300 nautical miles at a constant noise level of 112 PNdb. Further increases in takeoff speed result in only small improvements in range. With optimum matching at a ramp gross weight of 500,000 pounds the range is 2900 nautical miles when meeting design objectives of 160 knot takeoff speed and 105 PNdb community noise.

The effect of engine size and wing loading on design range and direct operating costs are presented in Figs. 3-15 and 3-16 for the GE4/J5G turbojet and STF 219B (2200°F) turbofan, respectively. Data are for a ramp gross weight of 500,000 pounds and design payload of 43,000 pounds. The community noise levels are shown for the SCAT 15F-B7 level of low speed performance; i.e., $C_{L_{LO}} = 0.60$ and climb out L/D = 6.0. It is noted that for the GE turbojet the economics of the configuration are comprised below noise levels of approximately 118 PNdb. The same is true with the P&W turbofan below noise levels of 112 PNdb. Engine weight scaling effects of the P&W turbofan are not as severe and, therefore, lowering the design noise level with this engine does not affect the range and economics as much as the GE turbojet. The engine size required to meet a given community noise level can be obtained from Figs. 3-17 and 3-18 for both engine cycles. The ratio of ramp gross weight to total engine airflow required is shown as a function of wing loading, takeoff lift coefficient. and second segment lift-drag ratio.

Airport noise and approach noise are shown for the GE4/J5G (Fig. 3-19) and the P&W STF 219B, 2200°F (Fig. 3-20) engines as a function of airflow. The SCAT 15F-B7 configuration with 560 pounds per second GE4/J5G engines has an airport noise of 118 PNdb and approach noise of 113 PNdb. This configuration sized with 600 pounds per second P&W STF 219B engines has an airport noise of approximately 117 PNdb and approach noise of 116.5 PNdb. As shown, the approach noise level would be lower if improved lift-drag ratios could be attained.

The trade between operating empty weight and supersonic cruise lift-drag ratio was investigated for the SCAT 15F canard configurations (Fig. 3-21). Data are shown for a constant range of 4000 statute miles for engine sizes of 560 pounds per second (112 PNdb community noise) and 650 pounds per second (105 PNdb community noise). In order to meet a design noise level of 105 PNdb the OEW of the SCAT 15F-B7 would have to be increased approximately 10,500 pounds because of the larger engine size required. This would necessitate a cruise lift-drag ratio of 10.3 in order to meet the design payload-range at a ramp gross weight of 500,000 pounds and wing loading of 62.5 psf.

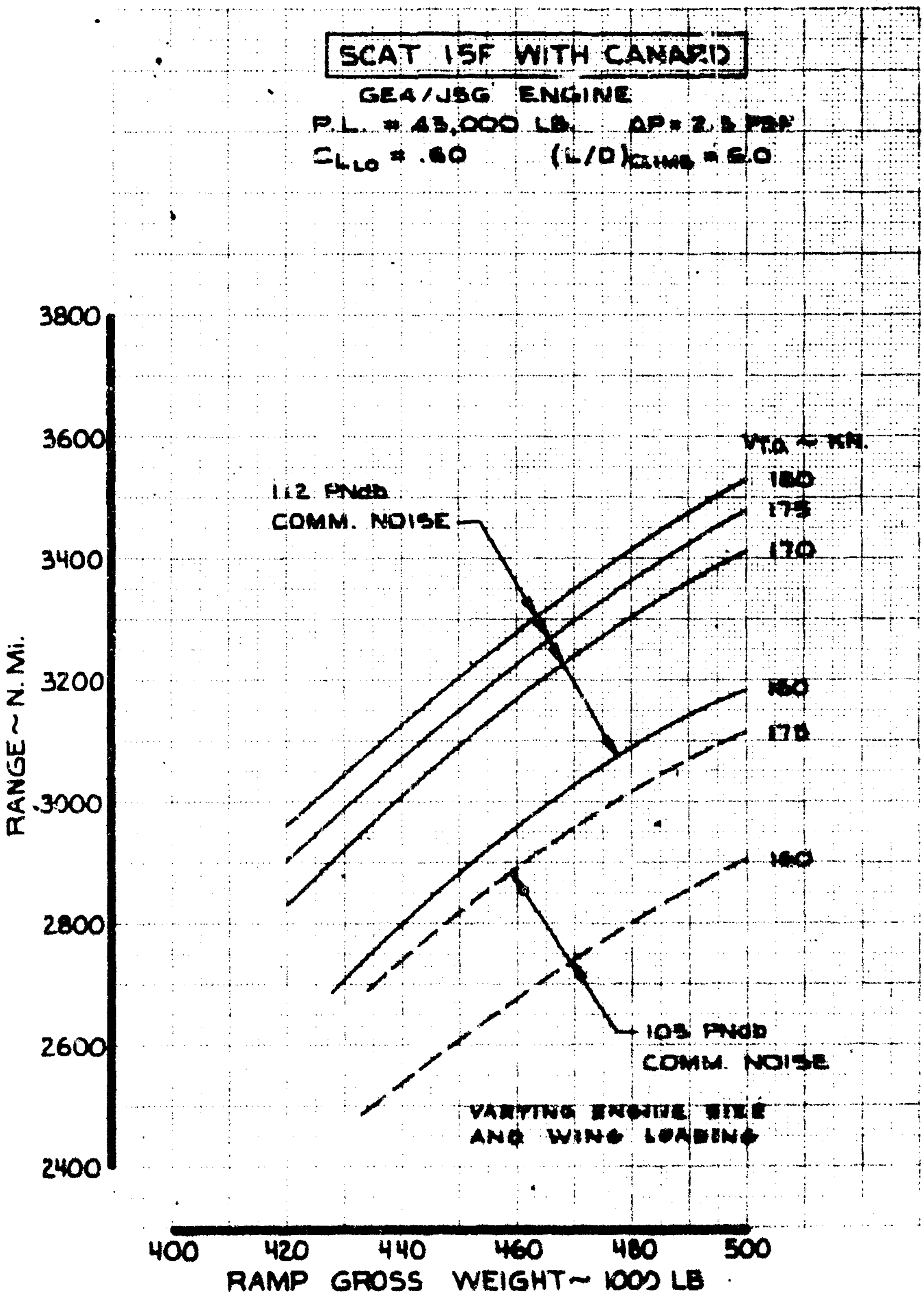


Fig. 3-14 Effect of Takeoff Speed

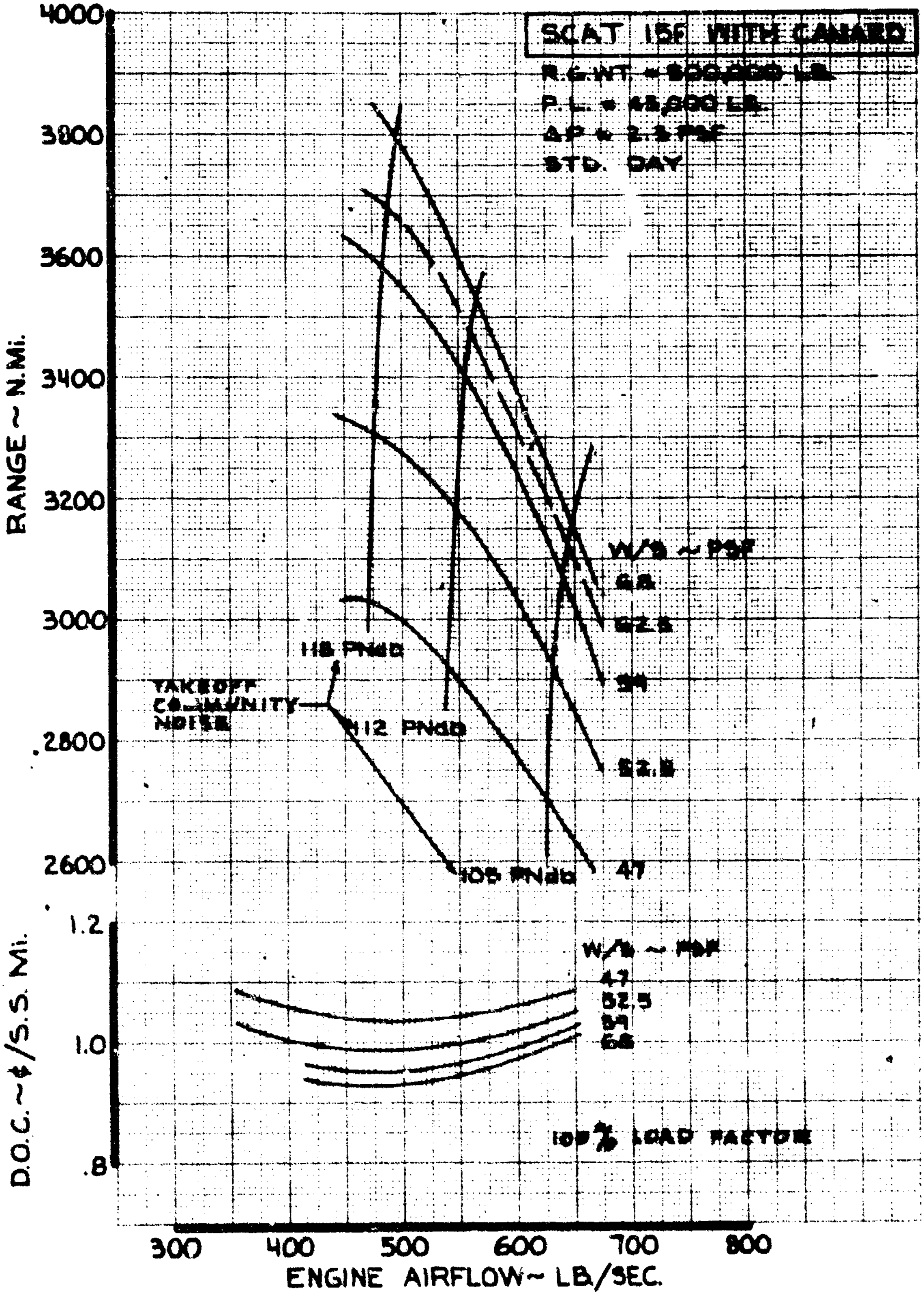


Fig. 3-15. Effect of Engine Size and Wing Loading on Range and D.O.C. - GE4/J5G

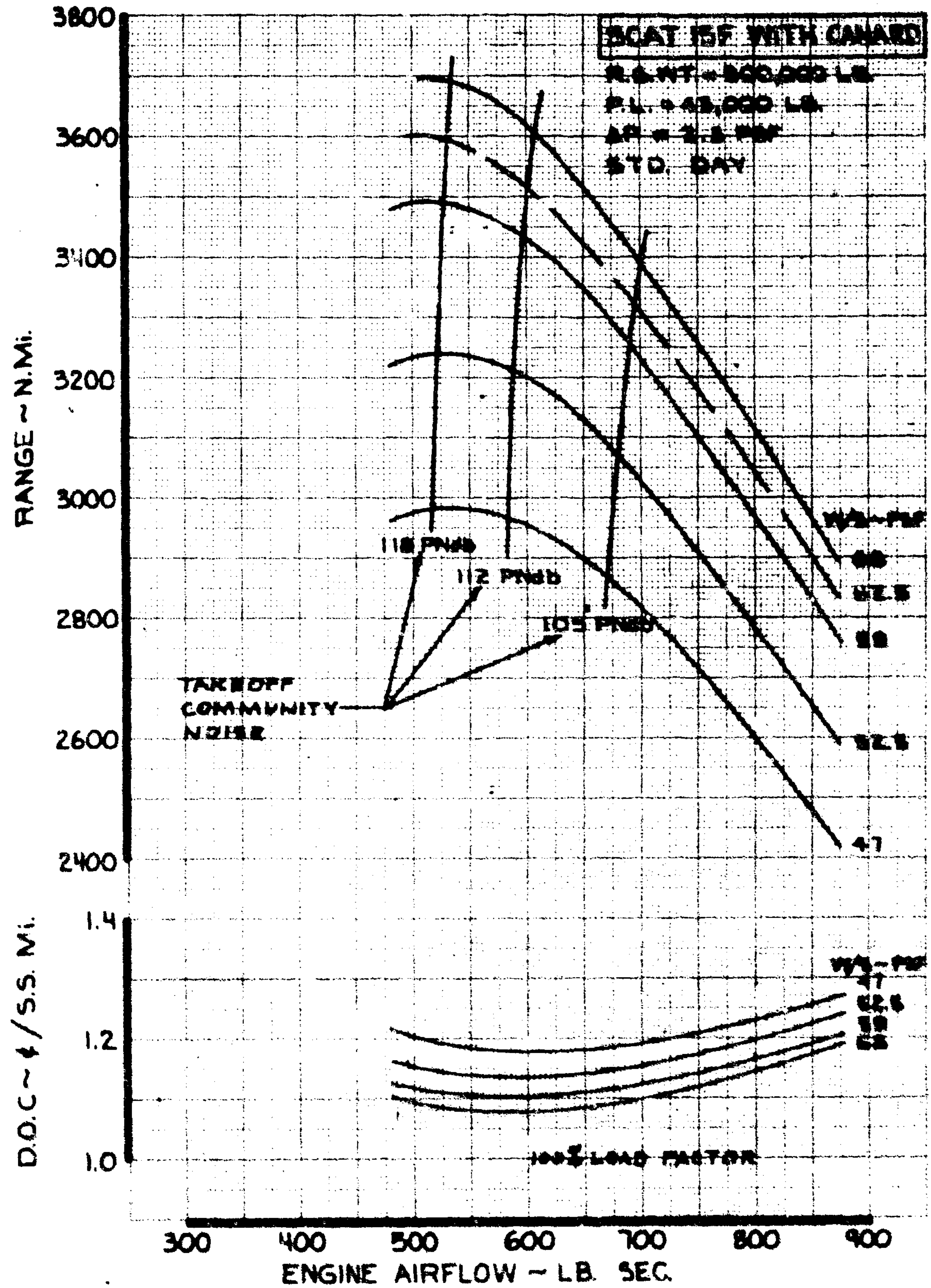


Fig. 3-16 Effect of Engine Size and Wing Loading on Range and D.O.C. - P&W STF219B (2200°F)

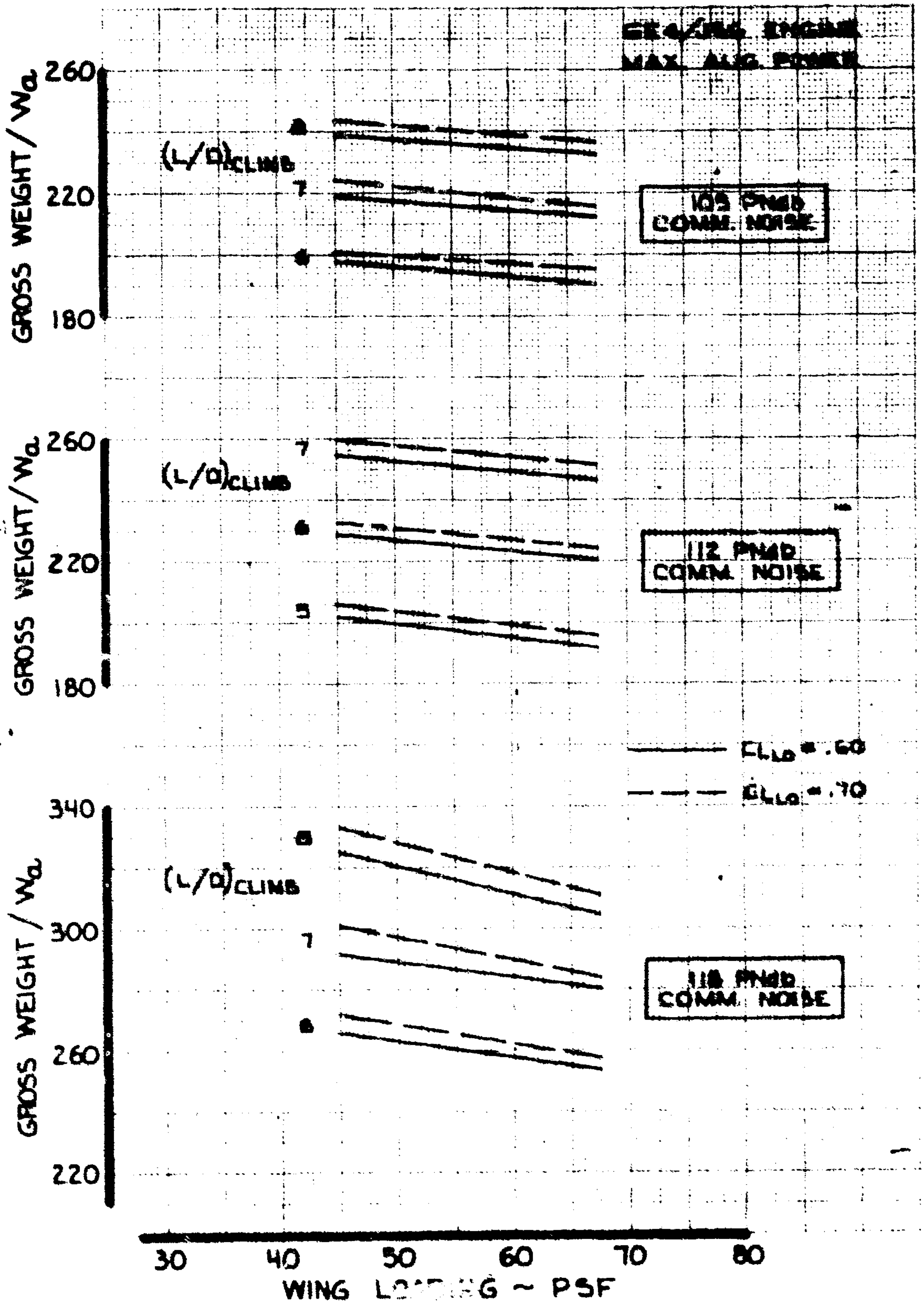


Fig. 3–17 Effect of Community Noise on Engine Size - GE4/J5G

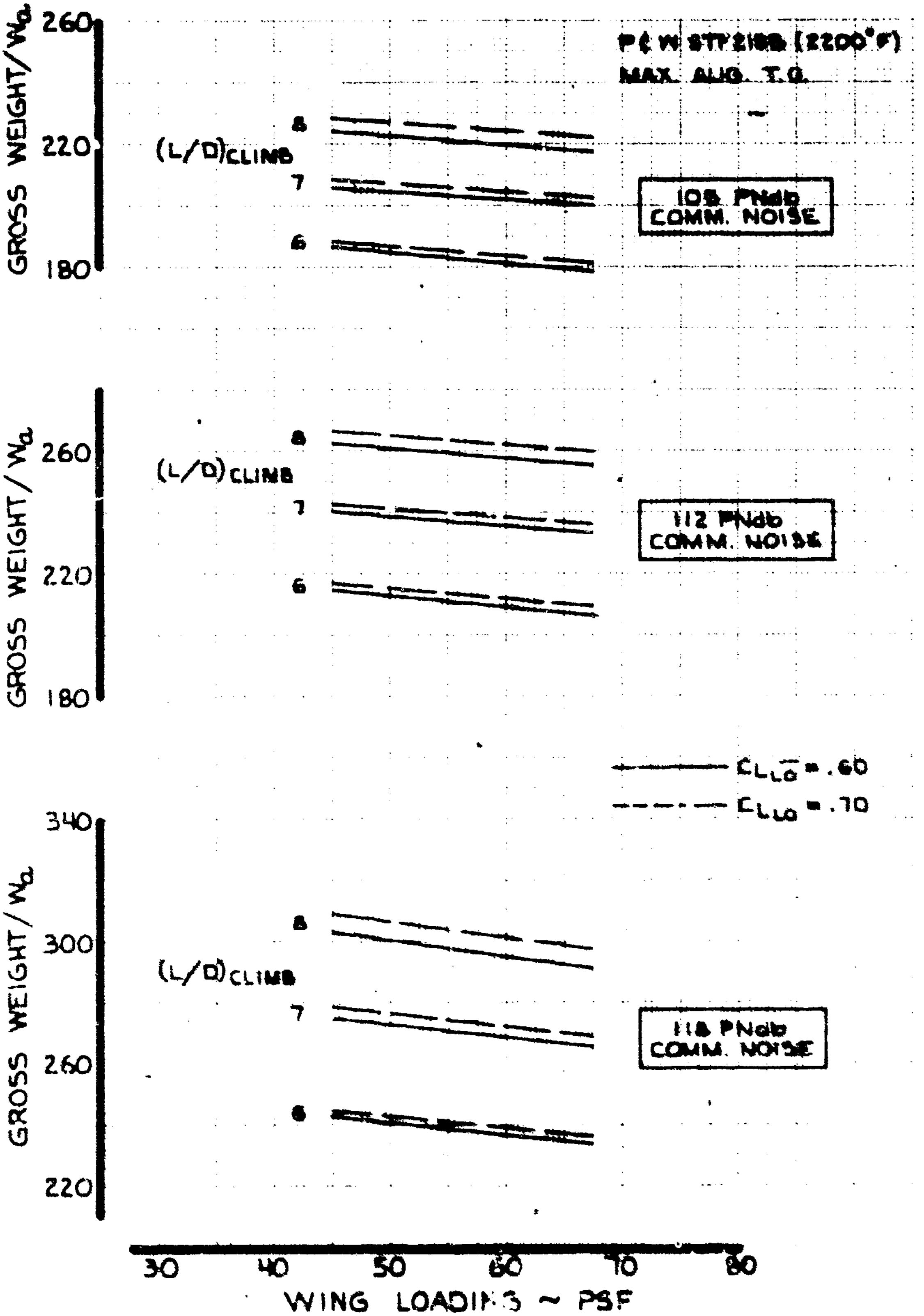


Fig. 3-18 Effect of Community Noise on Engine Size - P&W STF219B (2200°F)

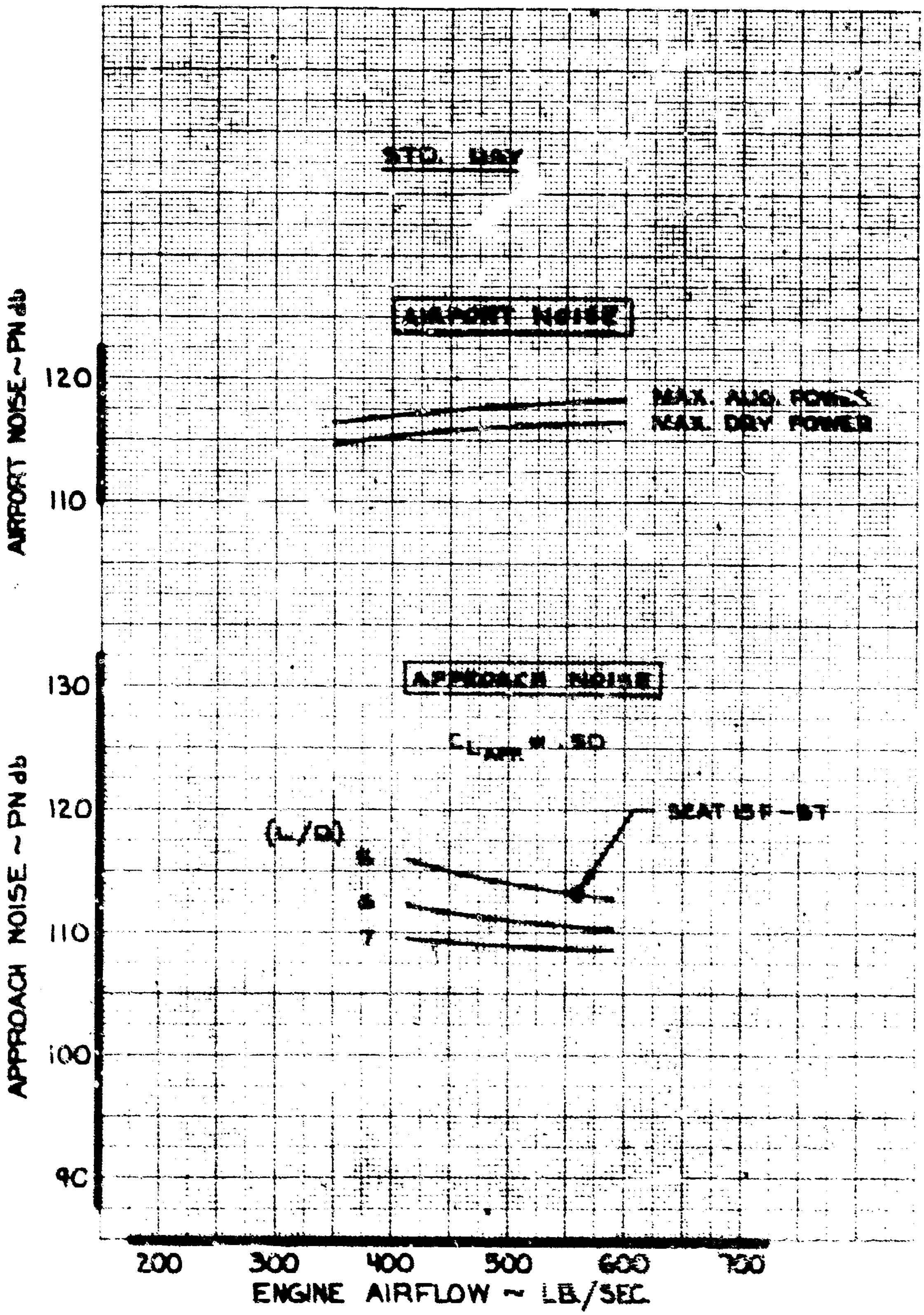


Fig. 3-19 Airport and Approach Noise GE4/J5G Engine

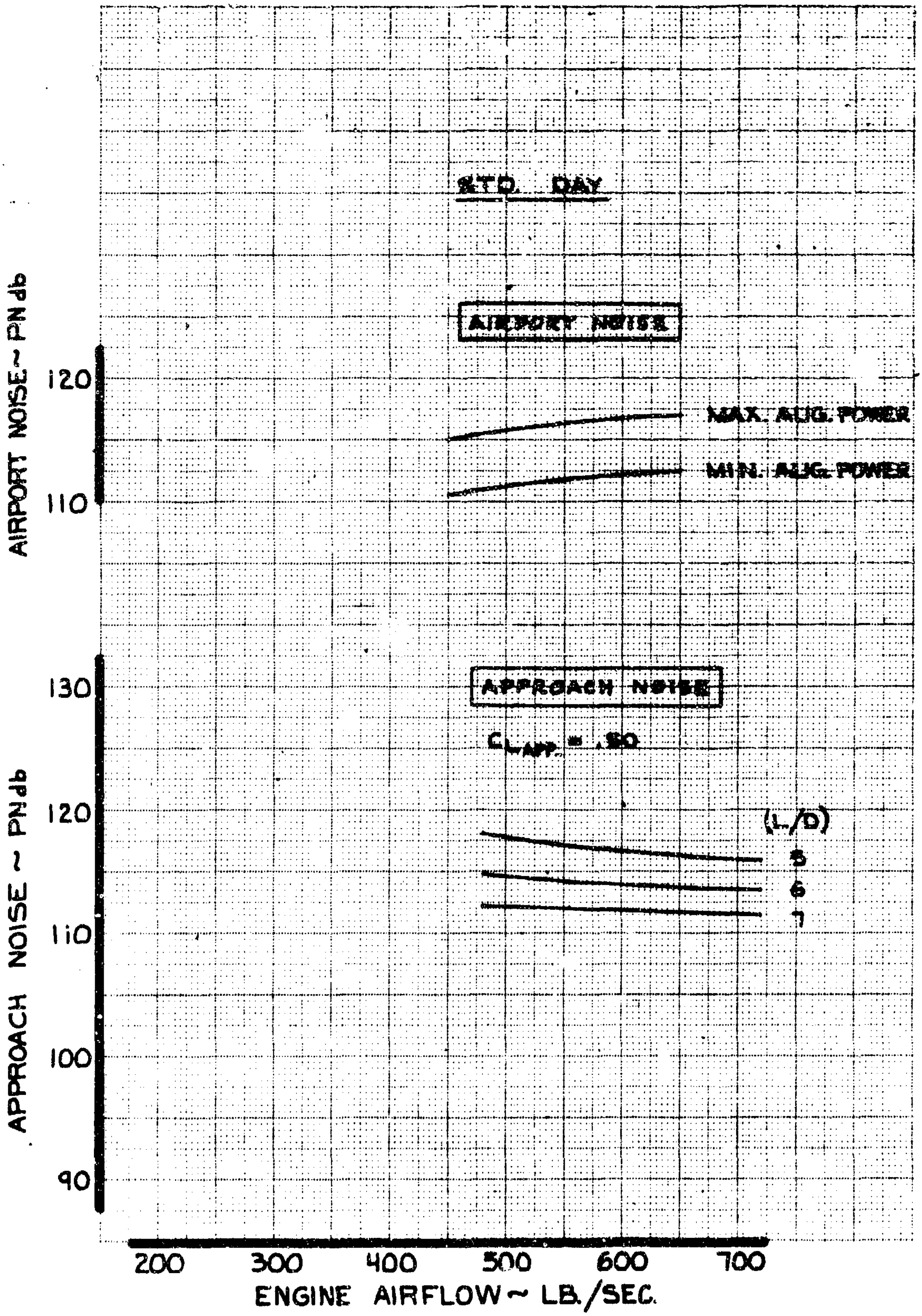


Fig. 3-20 Airport and Approach Noise P&W STF219B (2200°F) Engine

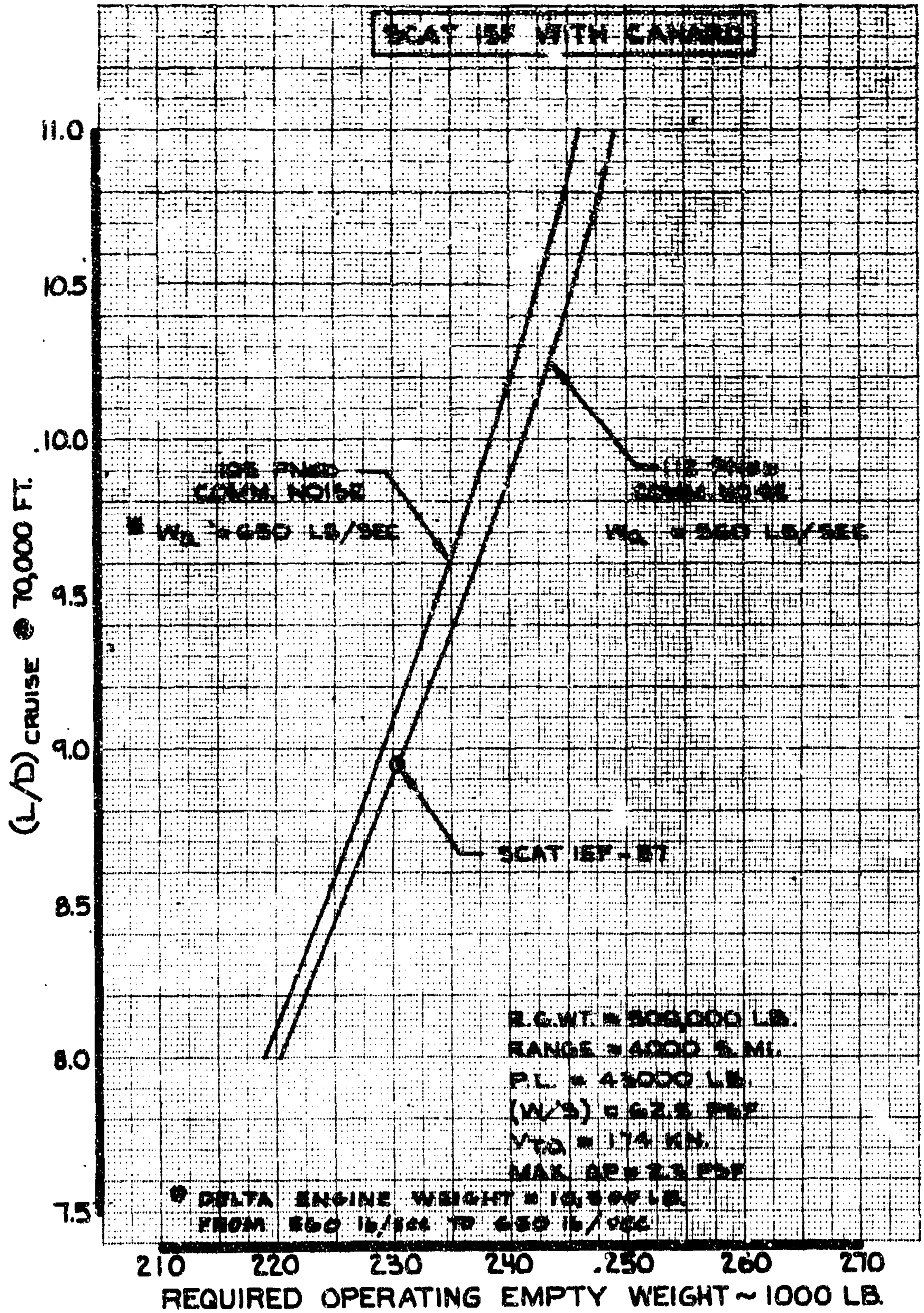


Fig. 3-21 (L/D) - OEW Trade

3.3 SUBSTANTIATION

3.3.1 Cruise Configuration

3.3.1.1 Drag Characteristics

The lift-drag ratio values for the SCAT 15F-B7 along a typical climb and acceleration schedule are given in Fig. 3-22. Also shown are the lift-drag ratios occurring during hold, missed approach, and alternate cruise. For subsonic operation the use of leading edge devices has been assumed and an increase in lift-drag ratio of approximately 1.0 has been included in the holding and alternate cruise phases of mission performance.

The supersonic cruise drag polar is shown in Fig. 3-23 for an altitude of 70,000 feet. The maximum lift-drag ratio at this altitude is 9.06. The cruise lift-drag ratio at maximum dry power is 8.95.

A typical variation of lift-drag ratio used for parametric performance studies is presented in Fig. 3-24 as a function of wing reference area. These data are given for the SCAT 15F-B7 body and engine size. The engine-airframe match for maximum nautical miles per pound of fuel reduces the lift-drag ratio approximately one percent for cruise.

3.3.1.2 Drag Analysis

The high speed drag data of the SCAT 15F-B7 are based on the wind tunnel data obtained from the NASA Langley Research Center. Extrapolation of the wind tunnel data to full-scale flight conditions have been obtained in two steps. First the wind tunnel data were extrapolated to flight conditions assuming identical external geometries for the wind tunnel model and the airplane. The resulting drag data were then corrected for the changes in geometry. The initial corrections were obtained directly from Ref. 3-1, Section 4, pages 83-167. It was assumed that changes applied to the wind tunnel model of the 733-290 would be applicable (after suitable scaling) to the wind tunnel model of the SCAT 15F-B7.

a. Skin Friction Correction

The method described in Ref. 3-1 was used allowing for changes in the Reynolds number. The correction based on $S_{ref} = 6954$ square feet is -0.0026 ΔC_D for Mach 2.7 and altitude of 70,000 feet. The internal drag correction was also modified in the light of the findings in Ref. 3-1. The modification increases the internal drag by $\Delta C_D = 0.000084$ and correspondingly reduced the external drag by the same amount.

b. Roughness drag

This was obtained from pages 132, 133 and 134 of Ref. 3-1 with the following changes. The wing, fuselage, engines, etc. were assumed to have the same roughness drag per unit wetted area as the

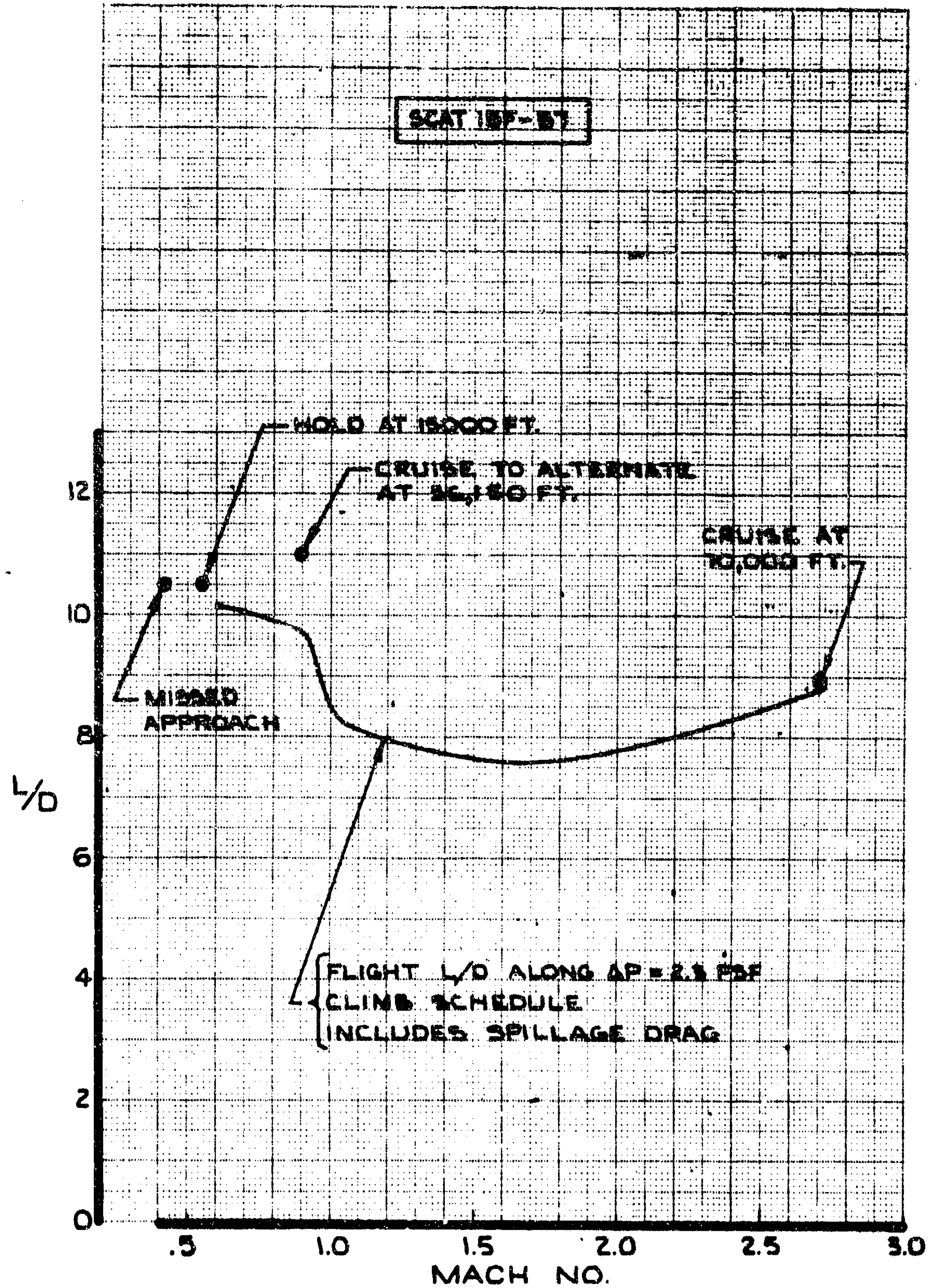


Fig. 3-22 Lift-Drag Ratios

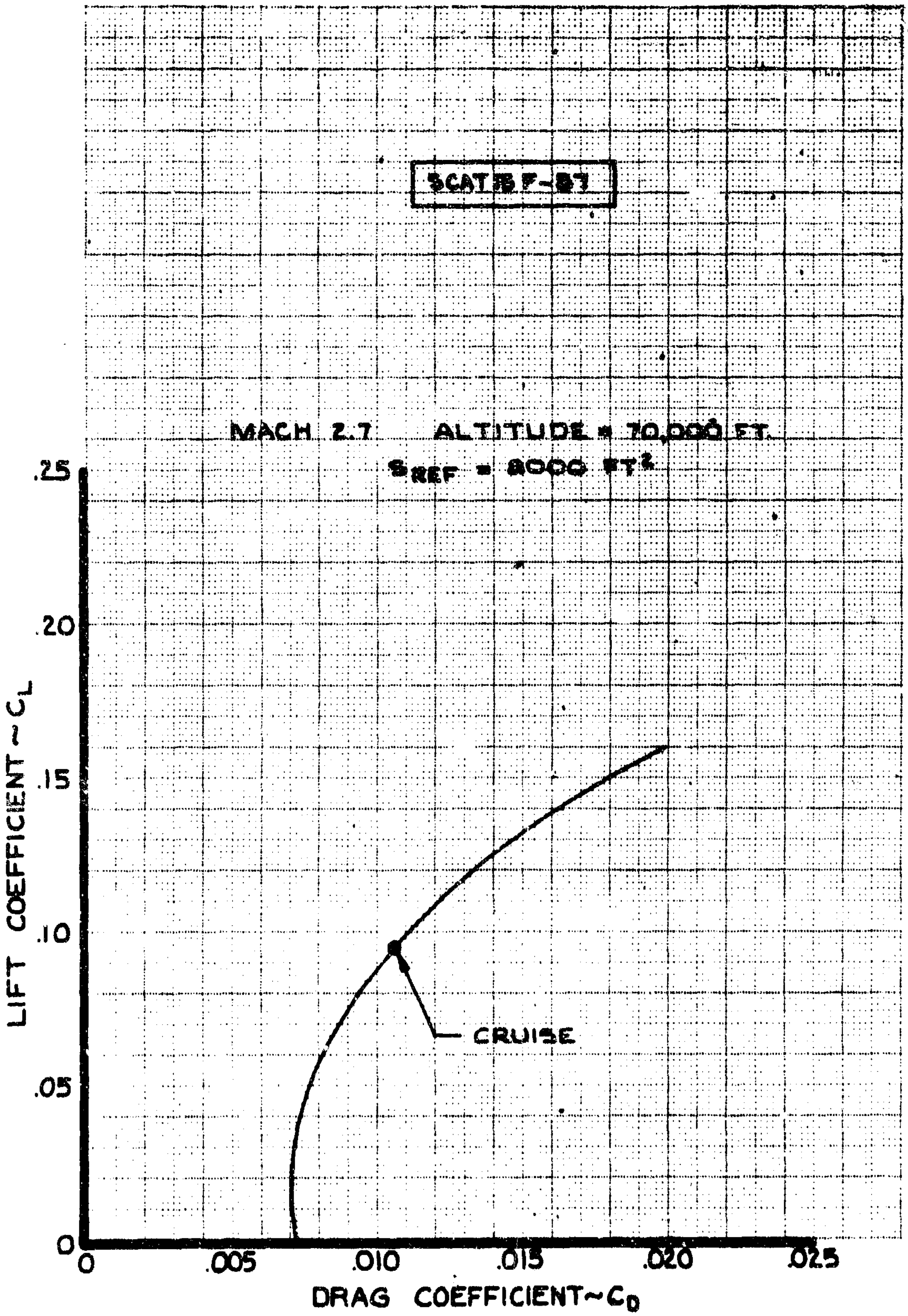


Fig. 3–23 Supersonic Cruise Drag Polar

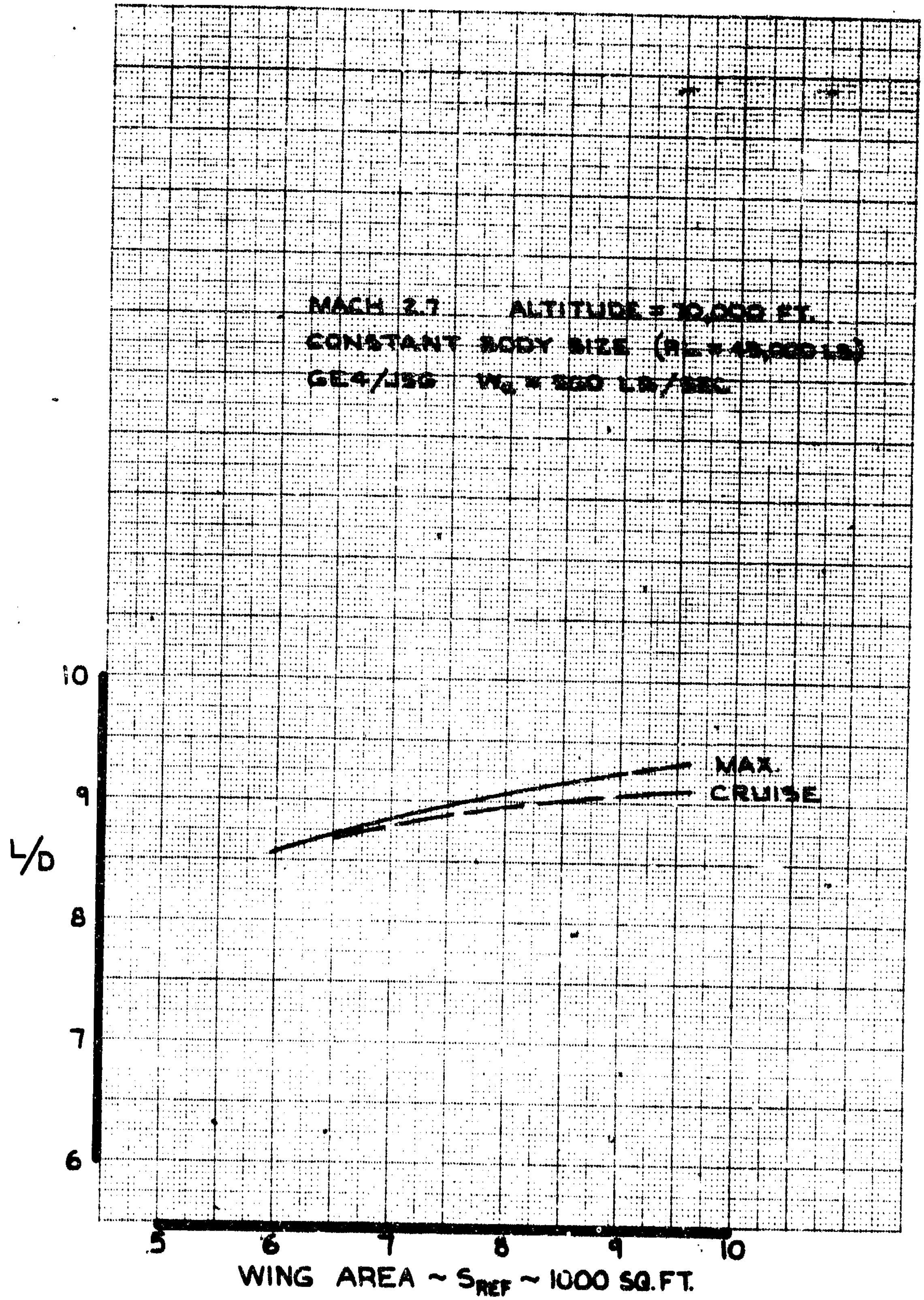


Fig. 3-24 Effect of Wing Area on Lift-Drag Ratio

corresponding components for the 733-290. The drag of the 733-290 miscellaneous items was retained. The roughness drag allowance at Mach 2.7 is 0.00017 ΔC_D based on an 8000 square foot wing area.

c. Wind Tunnel Model Body Closure Corrections

These were obtained directly from Fig. 4-32 of Ref. 3-1 and scaled for the ratio of body area to wing reference area.

d. Engine Effect Corrections

These were obtained from Ref. 3-1 but scaled in the ratio of engine thrust to wing reference area.

e. Trim Drag

No corrections were applied to the drag for aeroelasticity. These were found to be small for the 733-290 and would presumably be even smaller for the SCAT 15F-B7. There were no further corrections applied for trim drag. It is assumed that changes in C_{M_0} could be achieved by slight modifications to the nose of the fuselage and/or the twist of the wing in order to trim the aircraft without affecting the level of aerodynamic efficiency demonstrated by the wind tunnel model.

f. Changes To The Drag Due To External Geometry Variations

When the above mentioned corrections are applied to the wind tunnel model data, a maximum lift-drag of 9.44 results at Mach 2.7 and 70,000 feet. The SCAT 15F-B7 airplane, however, incorporates changes from the wind tunnel model that have affected the lift-drag ratio. The following corrections have been applied:

1. Skin Friction drag, $\Delta C_D = +0.0001$ due to a change in wetted area ratio from 2.88 to 3.03. A breakdown of wetted areas and skin friction drag is given in Table 3-D.

2. Pressure drag change due to planform modification and relative body size increases $\Delta C_D = +0.0001$. (This correction was estimated valid at $C_L = 0.1$, but applied as an increment for all lift coefficients.) It is assumed that a redesign in camber and twist will become necessary to achieve this level.

3. Drag increment due to increase in size and thickness ratio of the vertical tail, $\Delta C_D = +0.00009$.

Because of the changes in external geometry with the drag increments noted above, a degradation in lift-drag ratio from 9.44 to 9.06 occurs at Mach 2.7, 70,000 feet.

3.3.2 Takeoff and Landing Configuration

3.3.2.1 Low Speed Characteristics

Analysis of the SCAT 15F-220 configuration shows that sufficient lift cannot be generated for reasonable takeoff and landing speeds with a wing area sized for the required payload-range performance. One of the

Table 3-D Skin Friction Drag

SCAT 15F-B7

$S_{ref} = 8,000 \text{ Ft.}^2$

Reynolds No./Ft. = 1.22×10^6

Mach 2.70 Altitude = 70,000 Ft.

COMPONENT	$\frac{A_{WET}}{S_{REF}}$	L_{REF} FT.	C_{D_F}	
			METHOD A	METHOD B
WING PART I	.1235	17.6	.000204	.000208
WING PART II	1.445	87.5	.001835	.00188
BODY	.988	278.8	.00107	.00109
NACELLES	.305	35.9	.000448	.000457
VERTICAL TAILS	.1675	18.3	.000273	.00028
TOTAL	3.03		.0038	.0039

METHOD A: REFERENCE 3-2

METHOD B: REFERENCE 3-3

AVERAGE C_{D_F} = .00385

factors tending to limit the lift of this configuration is the requirement to trim to the forward CG which necessitates the use of upward deflected elevons. Use of downward deflecting trailing edge surfaces, with resulting increase in lift, requires a compensating positive moment. The approach that has been taken for the SCAT 15F-B7 has been to generate this moment with a high lift canard.

The takeoff and landing configuration of the SCAT 15F-B7 consists of plain flaps deflected downward to 16 degrees between the body and inboard nacelle; an elevon between nacelles drooped to 17 degrees and 23 degrees, respectively, for takeoff and approach; and a high lift canard. The inboard flap deflection angle is limited by ground clearance requirements when the airplane is rotated to its maximum ground angle. The elevon droop angle is determined by canard trimming capability during approach. For takeoff, the elevon droop angle was chosen to give a lift off C_L of 0.6 (see Par. 3.2.3). The canard is assumed to have slats and flaps as needed to generate a lift coefficient, based on canard exposed area, of at least $C_L = 2.5$. The center-of-gravity is at 42 percent MAC for takeoff and at 37 percent MAC for landing.

The SCAT 15F-B7 is a geometry limited airplane at liftoff and touchdown. That is, the speed at these conditions is determined by the maximum attitudes that the airplane can sustain on the ground, considering any margins required for prevention of damage to the airframe. More conventional airplanes of larger span generally fly at speeds referenced to a free air stall speed (V_{min}). However, model data used for evaluating the SCAT 15F-B7 indicated that a conventional stall would not occur at speeds that could influence this airplane's performance.

The low speed aerodynamic characteristics of the SCAT 15F-B7 airplane are shown on Fig. 3-25. The principal characteristics are listed in Table 3-E. Liftoff in ground effect is defined to occur at

Table 3-E Low Speed Characteristics

CONDITION	C.G.	δ_{FLAP}	δ_{ELEVON}	C_{L_c} (exposed area)	α°_{BODY}	C_L	L/D
LIFTOFF	42%	16°	17°	1.7	12.9	.600	—
CLIMB	"	"	"	"	12.3	.515	6.0
APPROACH	37%	16°	23°	2.5	11.9	.500	8.0
TOUCH D.	"	"	"	"	11.7	.525	—

the maximum ground attitude of the airplane with landing gear strut compressed. This procedure is unusual, based on present day operational techniques, in view of the fact that the pilot would probably rotate a little early to establish ground contact prior to reaching liftoff speed. This assumes that proper structure, perhaps a tail wheel, is

provided. A cockpit indication of ground contact might also be used. Liftoff at this condition must still leave sufficient margins of safety. The SCAT 15F-B7 can lift off at this attitude with only three engines operating without becoming second segment climb gradient limited ($\gamma_{2nd\ seg.} \geq 0.03$) even if no additional acceleration occurs after liftoff. In addition, an 8.0 percent speed margin over minimum unstick (V_{MU}) exists.

After liftoff, the airplane continues to accelerate during the flare. It was estimated that the speed during climb would be 8 percent greater than at liftoff. Although available wind tunnel data adjusted to full-scale conditions did not result in as high a lift-drag ratio for climb as was used for performance calculations, the values used are considered attainable. This optimism is based on expected improvement in drag characteristics that are typical when trailing edge flaps are deflected.

To prevent damage to the airplane, approach lift coefficient is based on a touchdown attitude that is 2.8 degrees less than the ground contact angle with landing gear struts extended. It is assumed that speed decreases 2.5 percent from approach speed during landing flare. Body attitude during approach with a 3 degree glide slope is 9 degrees relative to the horizon. Substantiated lift-drag ratio during approach with gear down is 4.8 which is close to the value of 5.0 used for performance calculations. Trailing edge flap effects on the drag polar are again expected to make up this difference.

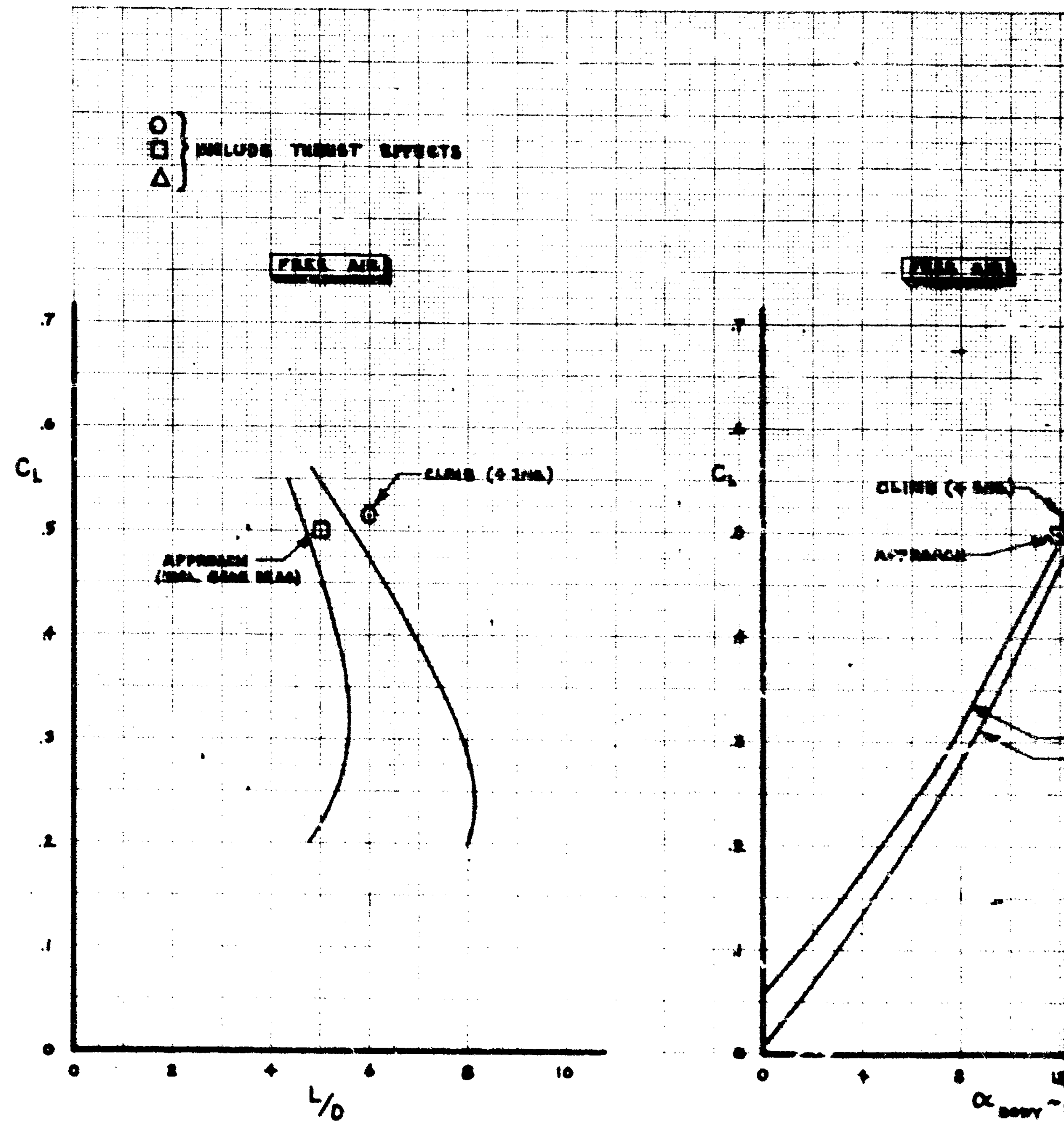
During approach, the airplane operates on the "back side" of the thrust required curve, indicative of speed instability. The approach speed is about 12 knots below the speed defining the limit of acceptable speed instability ($\frac{d\ t/w}{d_V} = -.0012$/knot).

3.3.2.2 Low Speed Analysis

The wind tunnel data used to estimate the low speed performance characteristics of the SCAT 15F-B7 airplane were obtained from NASA Langley Research Center. The results of three tests were used:

7 x 10 High Speed Tunnel, Test No. 650
30 x 60 Full Scale Tunnel, SCAT 15F free flight model force test
7 x 10 High Speed Tunnel, Test No. 681, Run in TDT.

Data from the first test provided lift, drag, and moment data with and without a ground board. Data from the second test was used to estimate trailing edge flap characteristics. Data from the third test provided the basis for estimating full scale induced drag characteristics. The models used in these tests were SCAT 15F models, differing only slightly from the planform of the SCAT 15F-B7 airplane. The wings were cambered and twisted. The wing leading edges were round, and leading edge flaps were used.



INCLUDE THRUST EFFECTS
FREE AIR
CLIMB
APPROACH
C_L
.7
.6
.5
.4
.3
.2
.1
0
0
2
4
6
8
10
L/D
FREE AIR

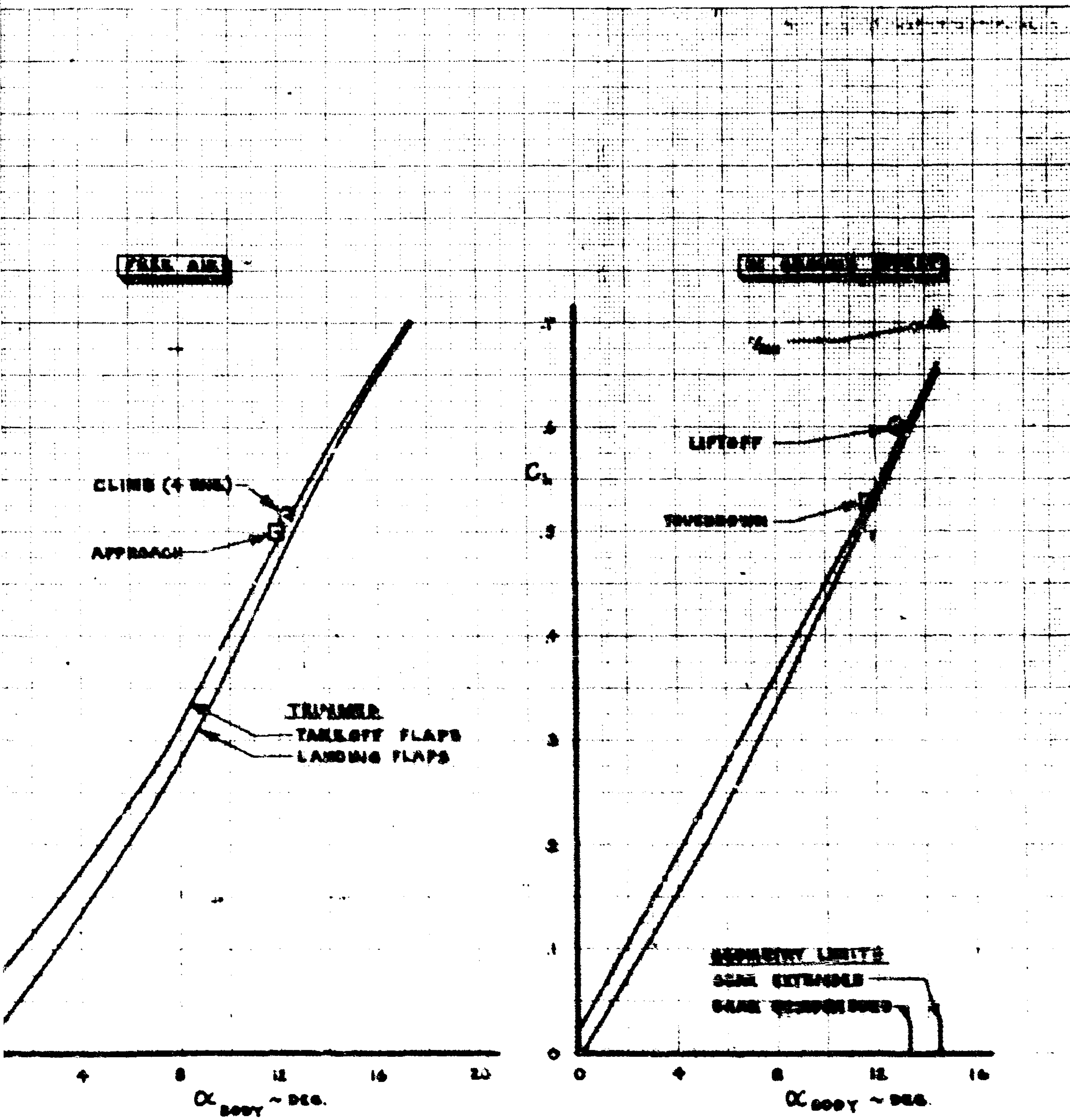


Fig. 3-25 Low Speed Characteristics

The wind tunnel values for lift and drag were adjusted for planform differences and estimated scale effects. Lift was increased 7 percent for Reynolds number effects. However, the lower aspect ratio of the SCAT 15F-B7 was estimated to decrease lift curve slope by 3 percent. Thus, a net increase in lift of 4 percent was applied. Pitching moment was not modified; it was assumed that the wing center of pressure remained in the same location relative to the mean aerodynamic chord when the planform was modified to the SCAT 15F-B7 planform. Lift and moment data are shown in Figs. 3-26 and 3-27.

Skin friction drag calculated for full scale airplane conditions and increments for pressure drag and engines were used to define C_{D_O} for the clean airplane. Induced drag characteristics, shown in Fig. 3-28, were extrapolated to high Reynolds number based on the results of recent NASA tests. The resulting drag polar is shown in Fig. 3-29.

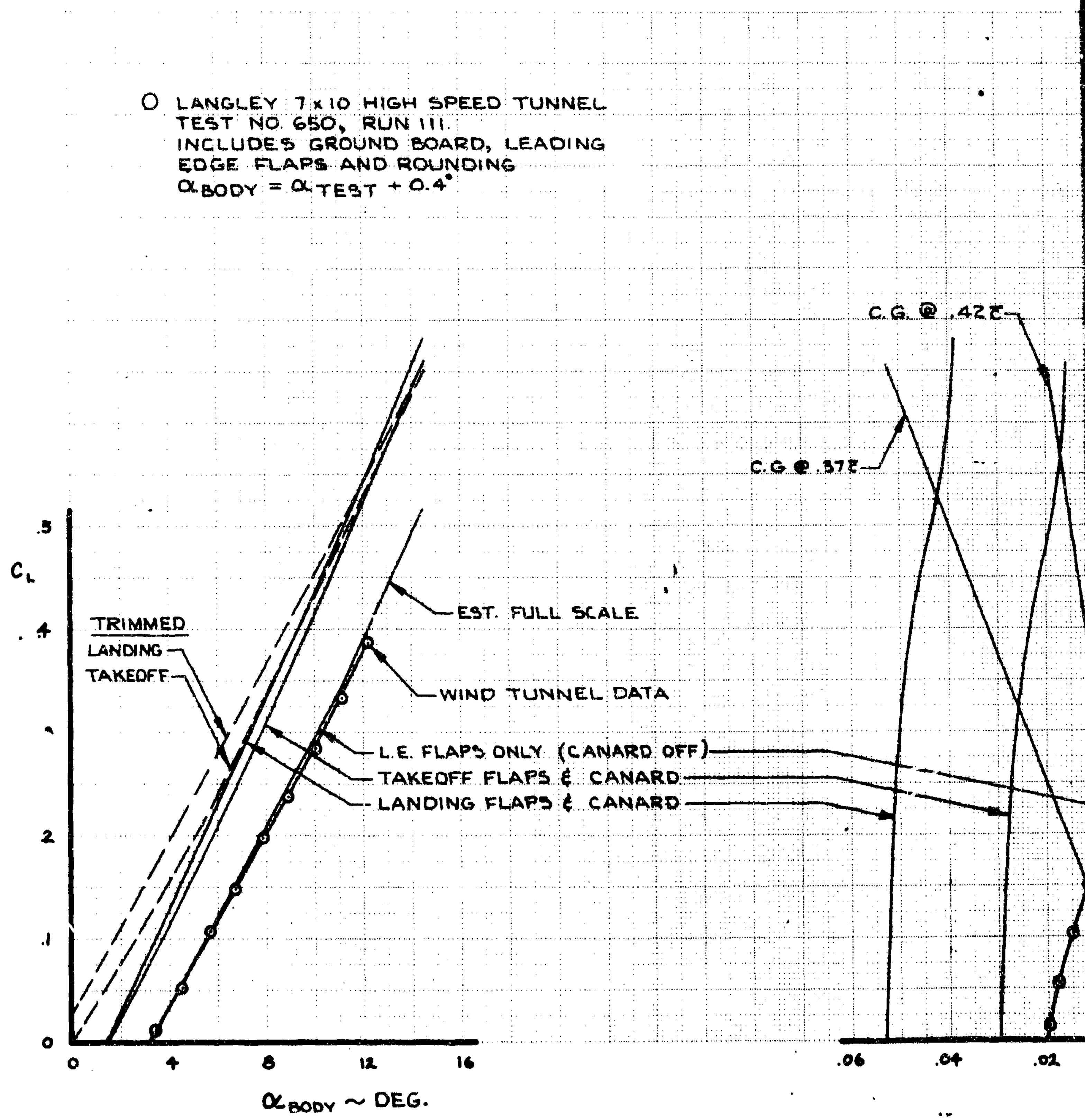
Additional lift and pitching moment from the flap and drooped elevon were estimated from the results of the force test of the free flight model of SCAT 15F. The effect of variations in flap size and location were included using simplified section theory to ratio incremental wind tunnel data. Some optimism was included to allow for refinements and scale effects. Increments for flap drag were not specifically included. Rather, it was assumed that increments in flap drag would be at least compensated by increments in lift sufficient to remain on the flaps-up polar. Experience with other wings and preliminary drag data from Test No. 650 (7 x 10 High Speed Tunnel) suggest that the drag polar will actually be improved. For this reason, the drag polar used for performance calculations is better than can be calculated using available data.

The canard, used to overtrim the airplane so that a flap and a drooped elevon could be used, has a straight wing planform of aspect ratio 3 based on exposed span and area. High lift flaps and a leading edge slat are assumed to be sufficiently powerful to allow a maximum lift coefficient of at least 2.5 based on exposed area. This is somewhat higher than generated by a similar canard on the free flight model. However, it is considered attainable for this planform.

The maximum canard lift is required during approach because of the forward center of gravity. During takeoff, canard lift would be reduced to an appropriate level by partial retraction of slats and flaps. It was assumed that one-half the canard lift would be cancelled by interference effects with the wing. Canard drag was computed using the equation:

$$\Delta C_{D_C} = 0.0002 + \frac{C_{L_C}^{2}}{0.8\pi AR_C}$$

where the coefficients and aspect ratio are based on the exposed planform.


O LANGLEY 7 x 10 HIGH SPEED TUNNEL
TEST NO. 650, RUN 111.
INCLUDES GROUND BOARD, LEADING
EDGE FLAPS AND ROUNDING
$\alpha_{BODY} = \alpha_{TEST} + 0.4°$
C.G. @ .42c̄
C.G @ .37c̄
EST. FULL SCALE
WIND TUNNEL DATA
TRIMMED
LANDING
TAKEOFF
L.E. FLAPS ONLY (CANARD OFF)
TAKEOFF FLAPS & CANARD
LANDING FLAPS & CANARD
C_L
.5
.4
.2
.1
0
0
4
8
12
16
α_{BODY} ~ DEG.
.06
.04
.02

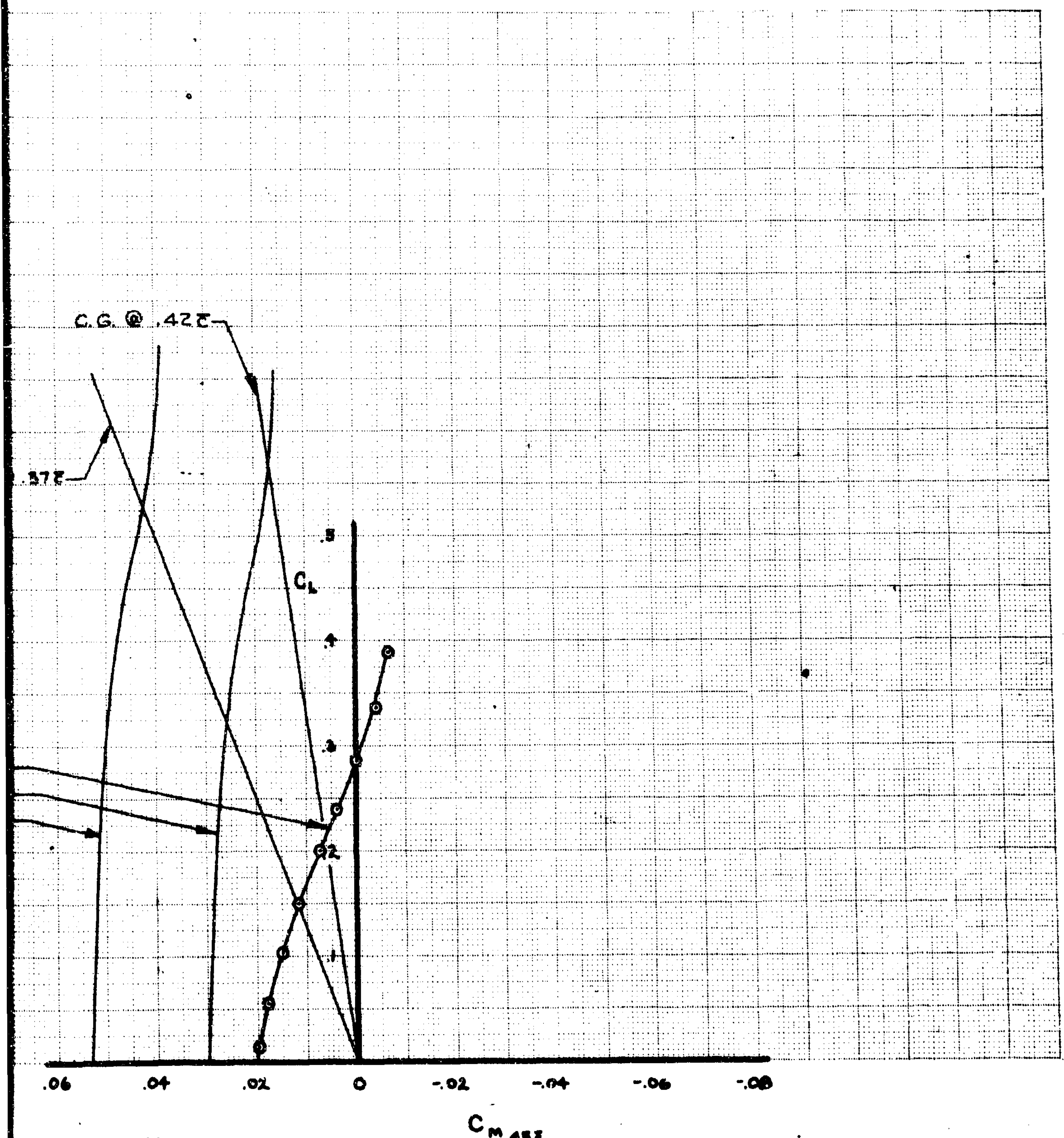
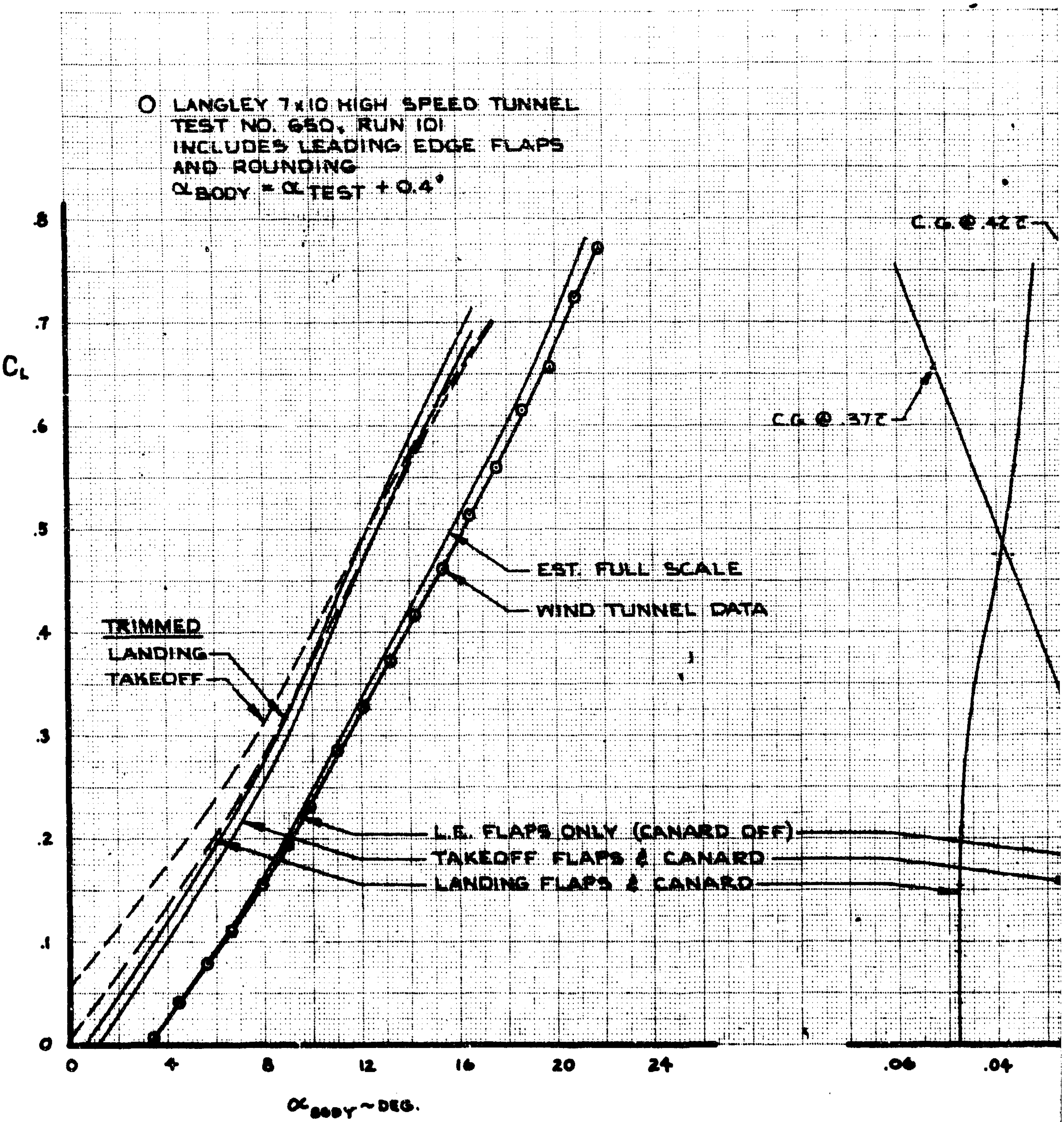


Fig. 3-26 Low Speed Lift and Moment in Ground Effect



O LANGLEY 7x10 HIGH SPEED TUNNEL
TEST NO. 650, RUN 101
INCLUDES LEADING EDGE FLAPS
AND ROUNDING
α BODY = α TEST + 0.4°
C.G. @ .42 c̄
C.G. @ .37 c̄
C_L
EST. FULL SCALE
WIND TUNNEL DATA
TRIMMED
LANDING
TAKEOFF
L.E. FLAPS ONLY (CANARD OFF)
TAKEOFF FLAPS & CANARD
LANDING FLAPS & CANARD
0
.1
.2
.3
.4
.5
.6
.7
.8
0
4
8
12
16
20
24
.06
.04
α BODY ~ DEG.

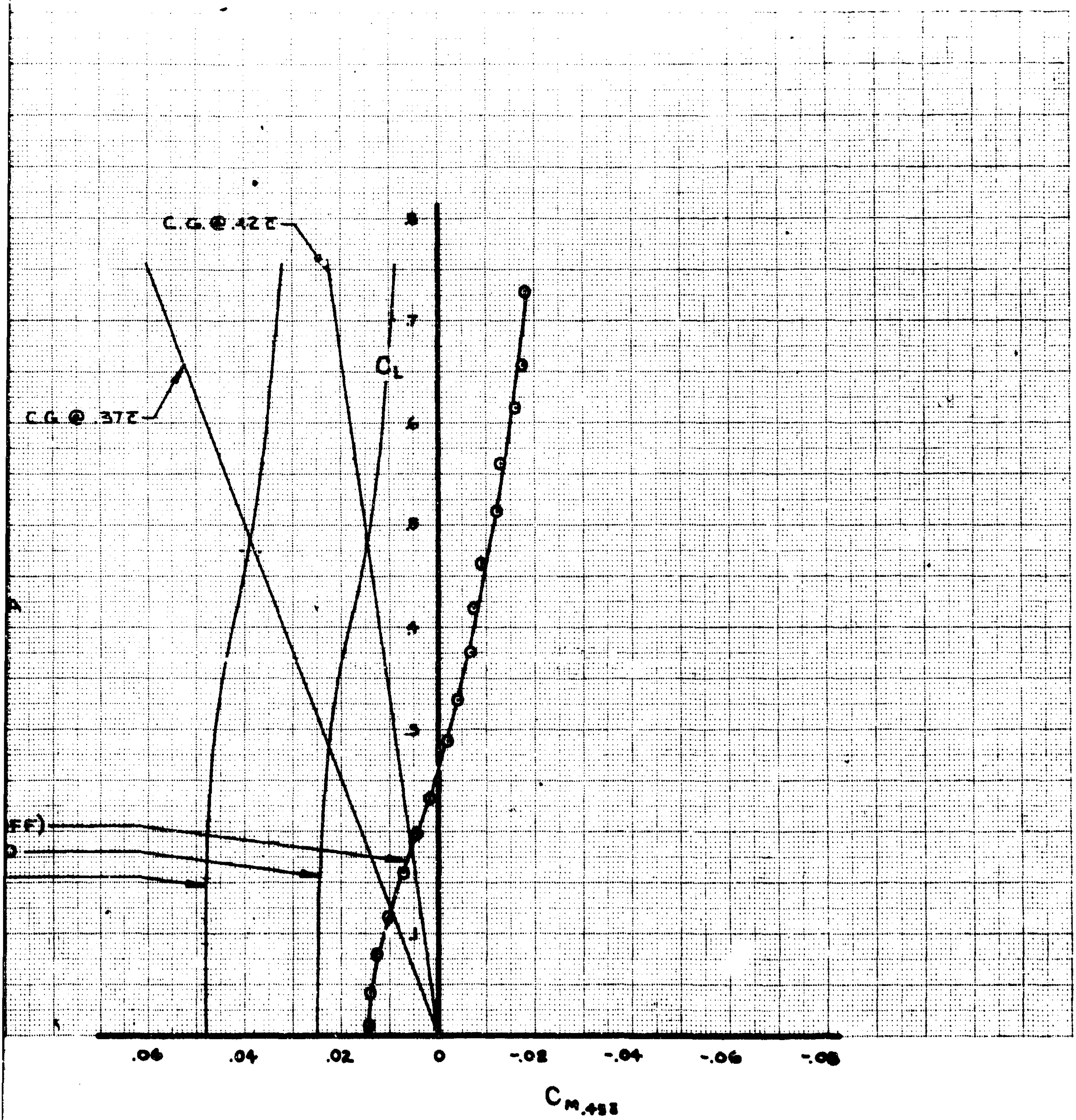


Fig. 3-27 Low Speed Lift and Moment in Free Air

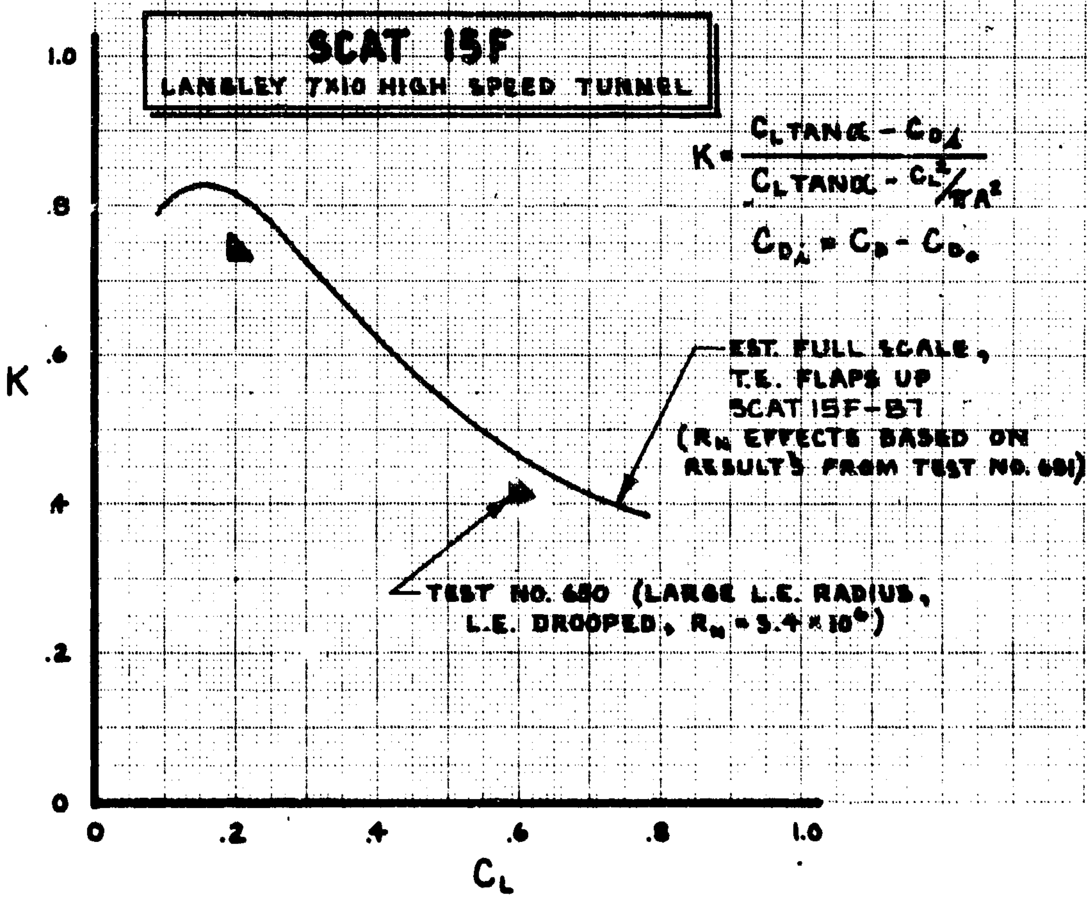


Fig. 3-28 Low Speed Induced Drag Factor

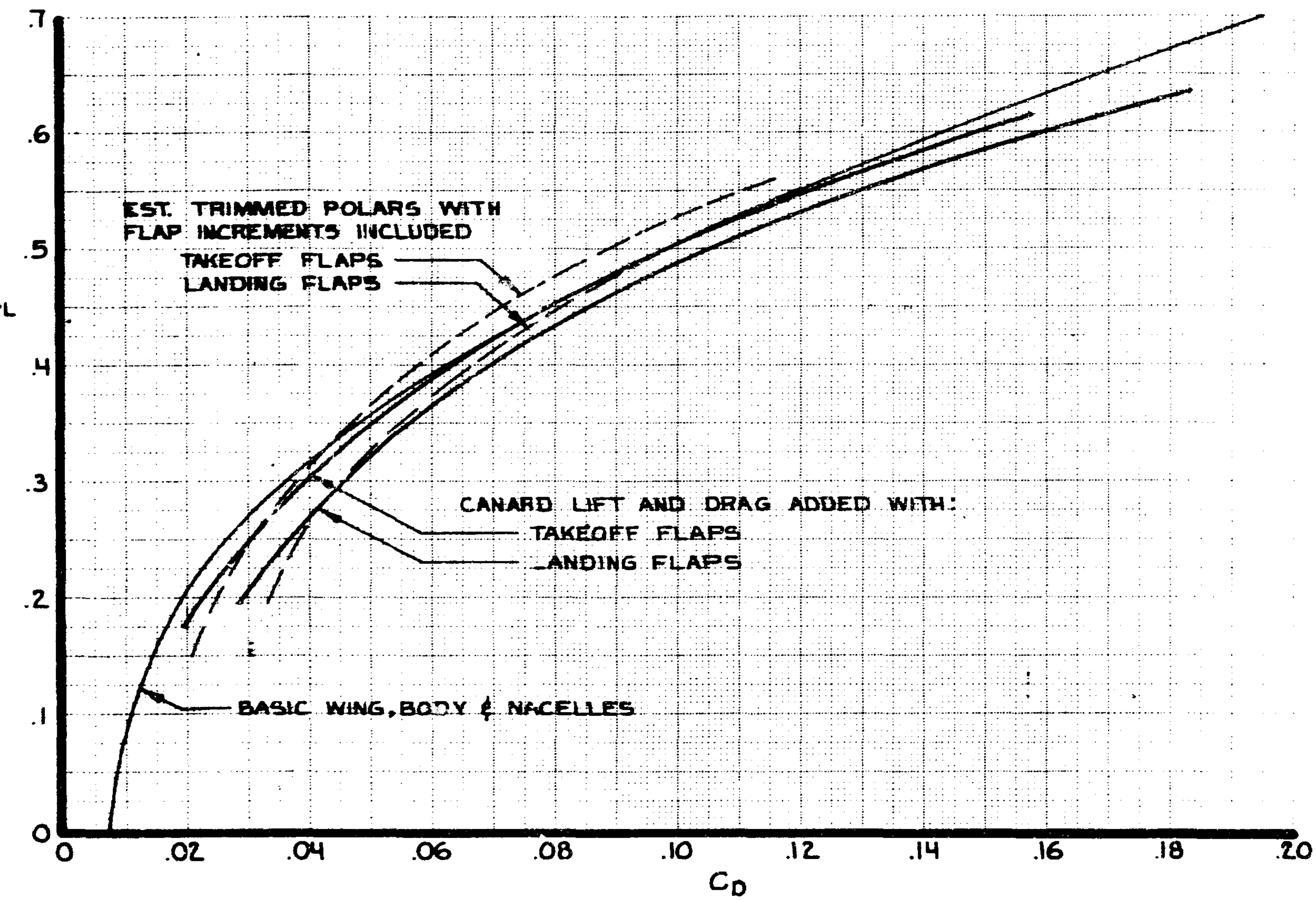


Fig. 3-29 Low Speed Drag Polar

3.3.3 Sonic Boom Characteristics

The sonic boom for the SCAT 15F was initially evaluated on the basis of the non-dimensional plot shown in Fig. 3-30. This plot had been obtained from the NASA and represents a calculation for the basic SCAT 15F. In order to resize the airplane, a family of sonic boom curves was prepared from which the effect of wing area changes was estimated. This is shown in Fig. 3-31. The final sonic boom data has been prepared using the methods described in Ref. 3-1 and the results are shown in Fig. 3-32 for Mach 2.7. The area distribution function S(x) and the lift distribution B(x) are shown in Fig. 3-33 for the SCAT 15F-B7.

All sonic boom calculations are based on methods standardized by the FAA for Phase II-A evaluation. Therefore, none of the potential benefits of the more detailed analysis of the general theory have been considered in this study.

3.3.4 Stability and Control

3.3.4.1 Longitudinal

a. Static Balance

The longitudinal balance and static stability for the SCAT 15F-B7 supersonic transport are shown in Fig. 3-34. The stability and control aerodynamic characteristics of the SCAT 15F-B7 have been derived from NASA wind tunnel data. Where necessary, corrections have been made to full scale geometry and conditions (see Par. 3.3.2 for Low Speed Corrections - M = 2.7 corrections were derived from supersonic, linearized flat plate analyses). Results derived from wind tunnel data and structural aeroelastic analyses show the aft CG limit at 46 percent MAC. This limit was selected to provide maneuver stability for the flexible airplane at M = 2.7. Airplane loading requirements dictate a 9 percent CG range thereby fixing the forward CG limit at 37 percent MAC.

The rigid aerodynamic center in the linear $\frac{dC_m}{dC_L}$ range varies from a 55 percent MAC at cruise (M = 2.7) to 47 percent at low speed (M = 0.20). This a.c. range represents the most aft location in the low C_L linear $\frac{dC_m}{dC_L}$ range (correspondingly, the best stability) and moves forward as stability reduces at higher lift coefficients (see Fig. 3-35). However, wind tunnel data indicate that addition of leading-edge flaps and/or radius enlargement improves low-speed stability and results in a 52 percent a.c. location for low-speed operation. These leading-edge devices will be required up to about M = 0.9 where they can be retracted.

Figure 3-35 indicates the range of lift coefficients for which linear stability is applicable; level or maneuvering flight conditions above this range will result in a forward shift of the a.c. (non-

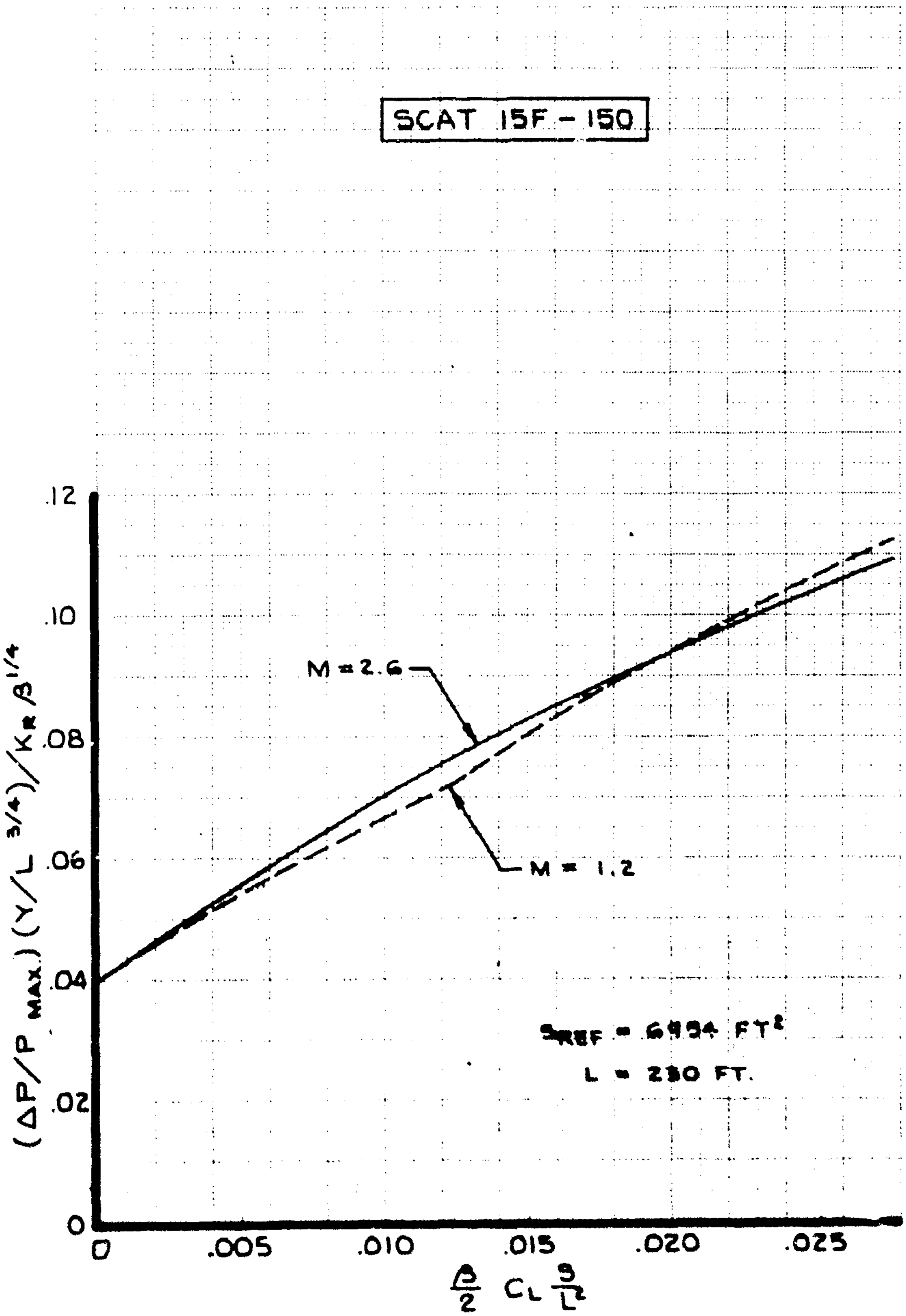


Fig. 3-30 Theoretical Far Field Sonic Boom Characteristics

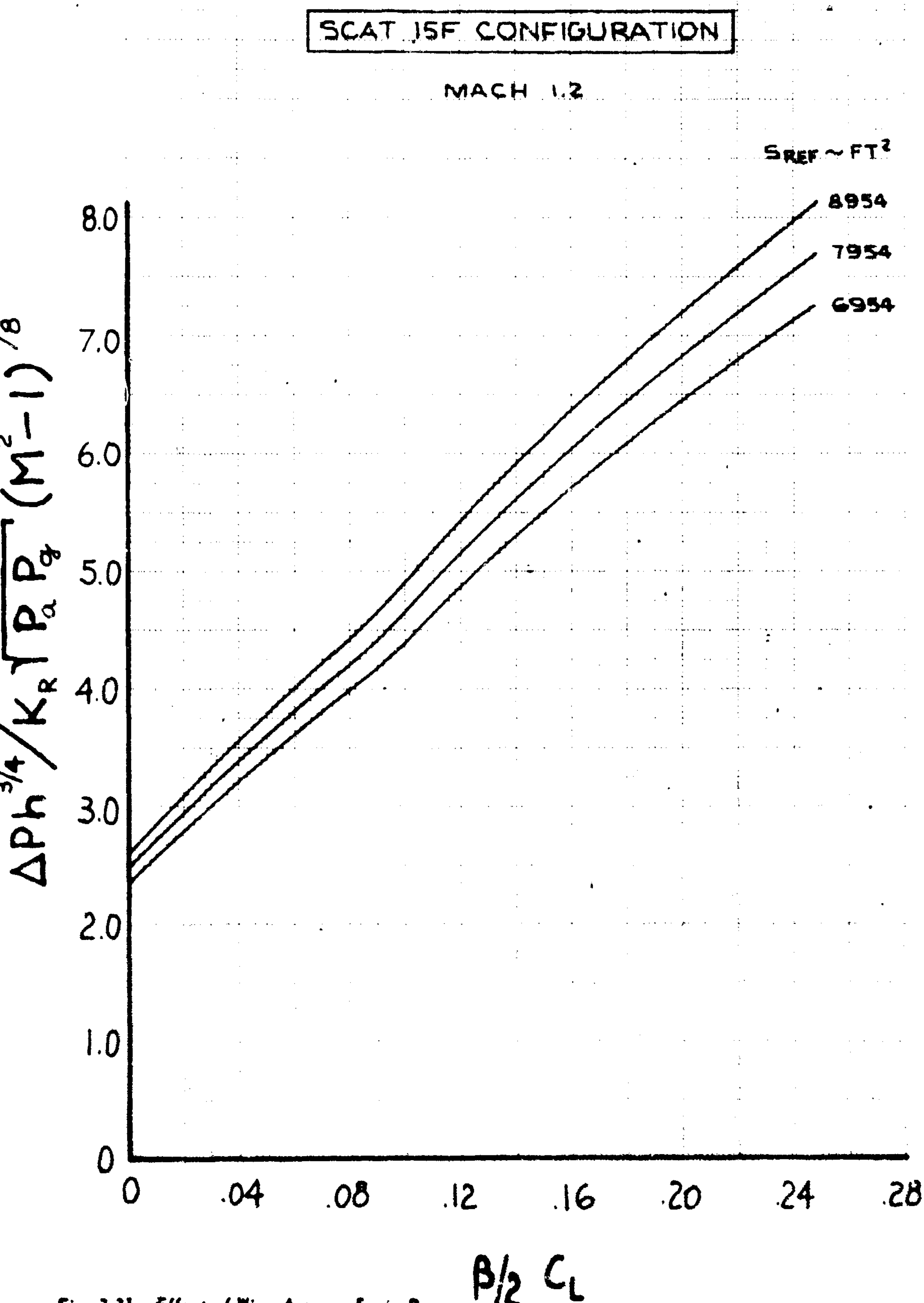


Fig. 3-31 Effect of Wing Area on Sonic Boom

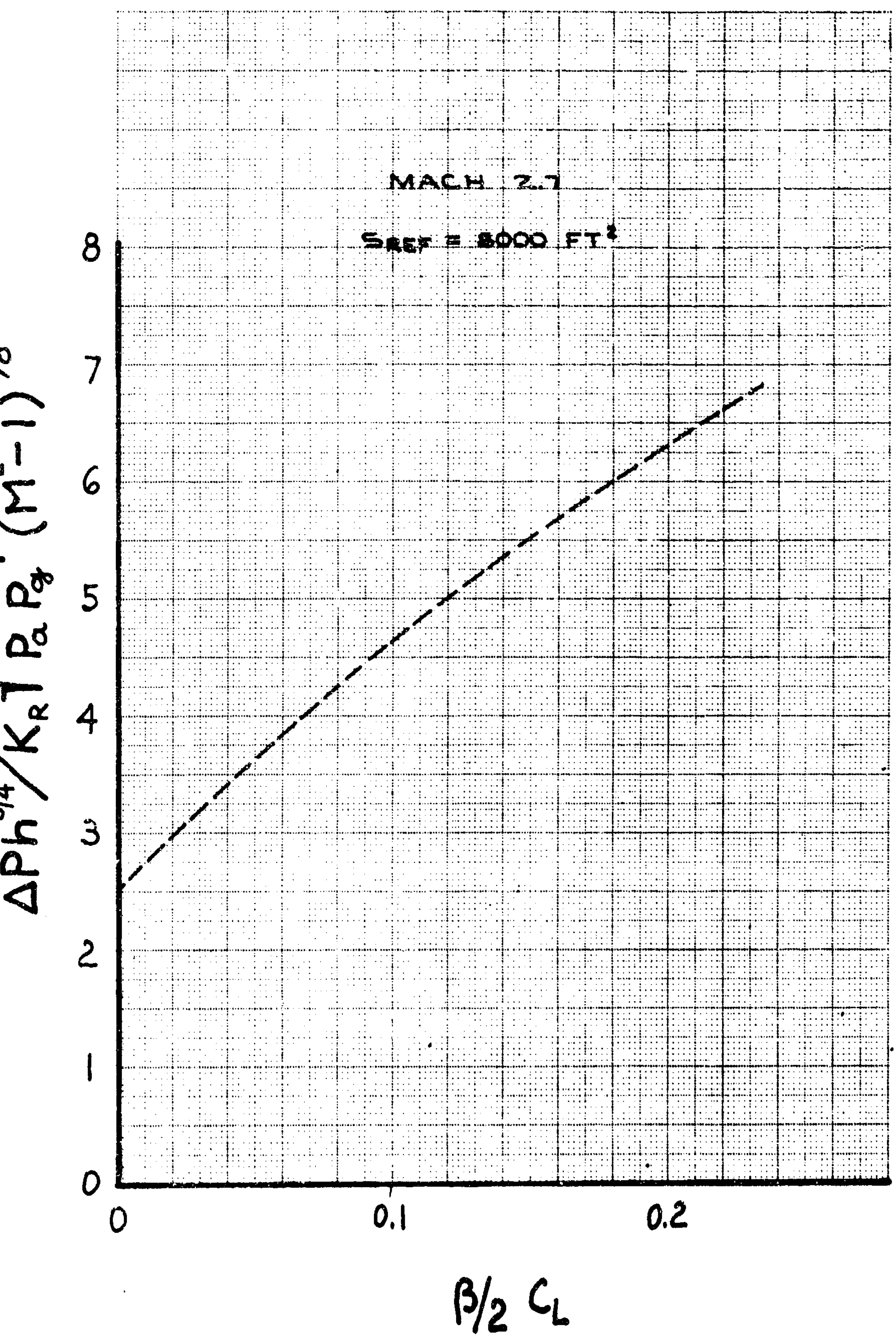


Fig. 3-32 Sonic Boom Characteristics SCAT 15F-B7

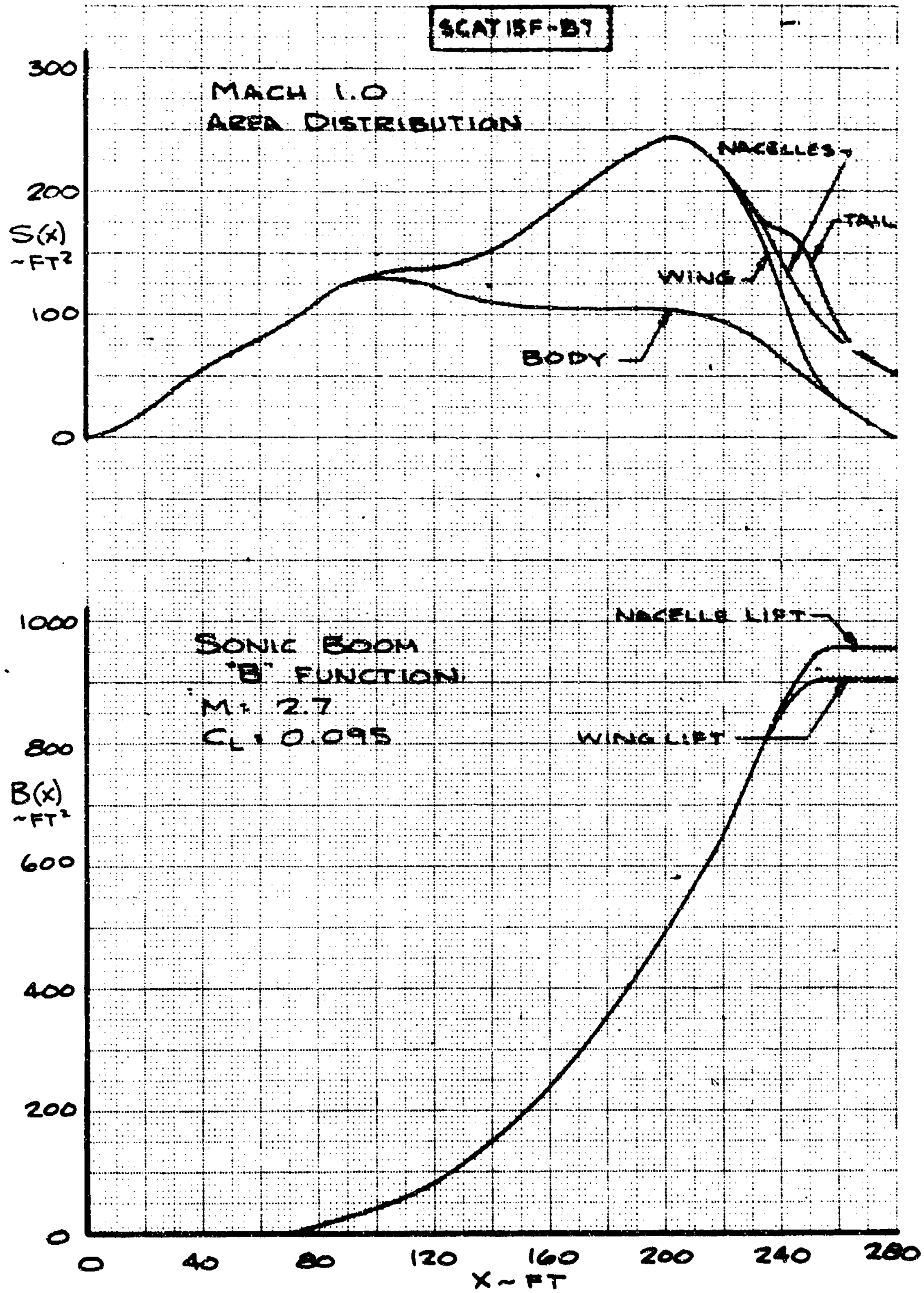


Fig. 3-33 Mach 1.0 Area Distribution

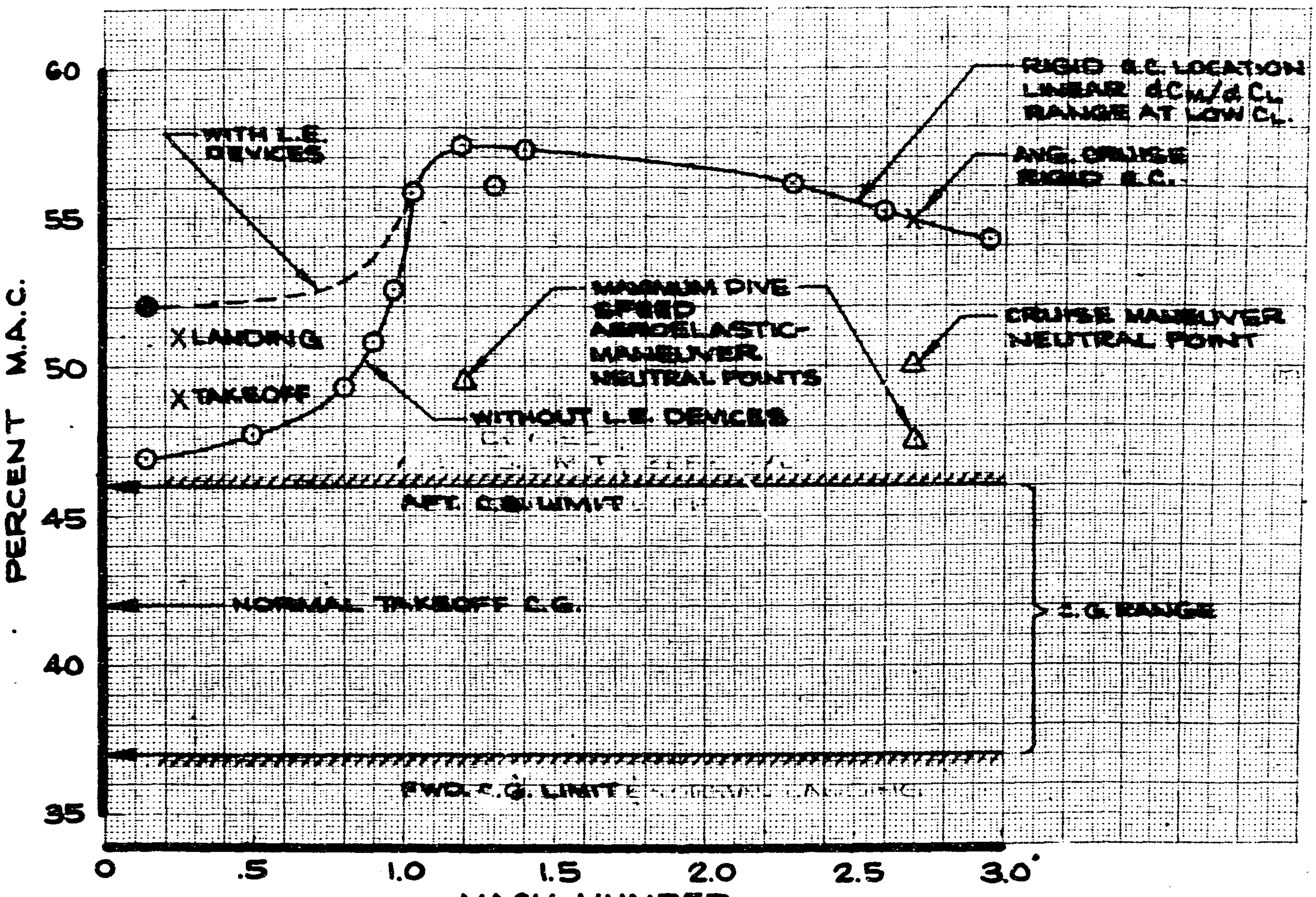


Fig. 3–34 Static Balance

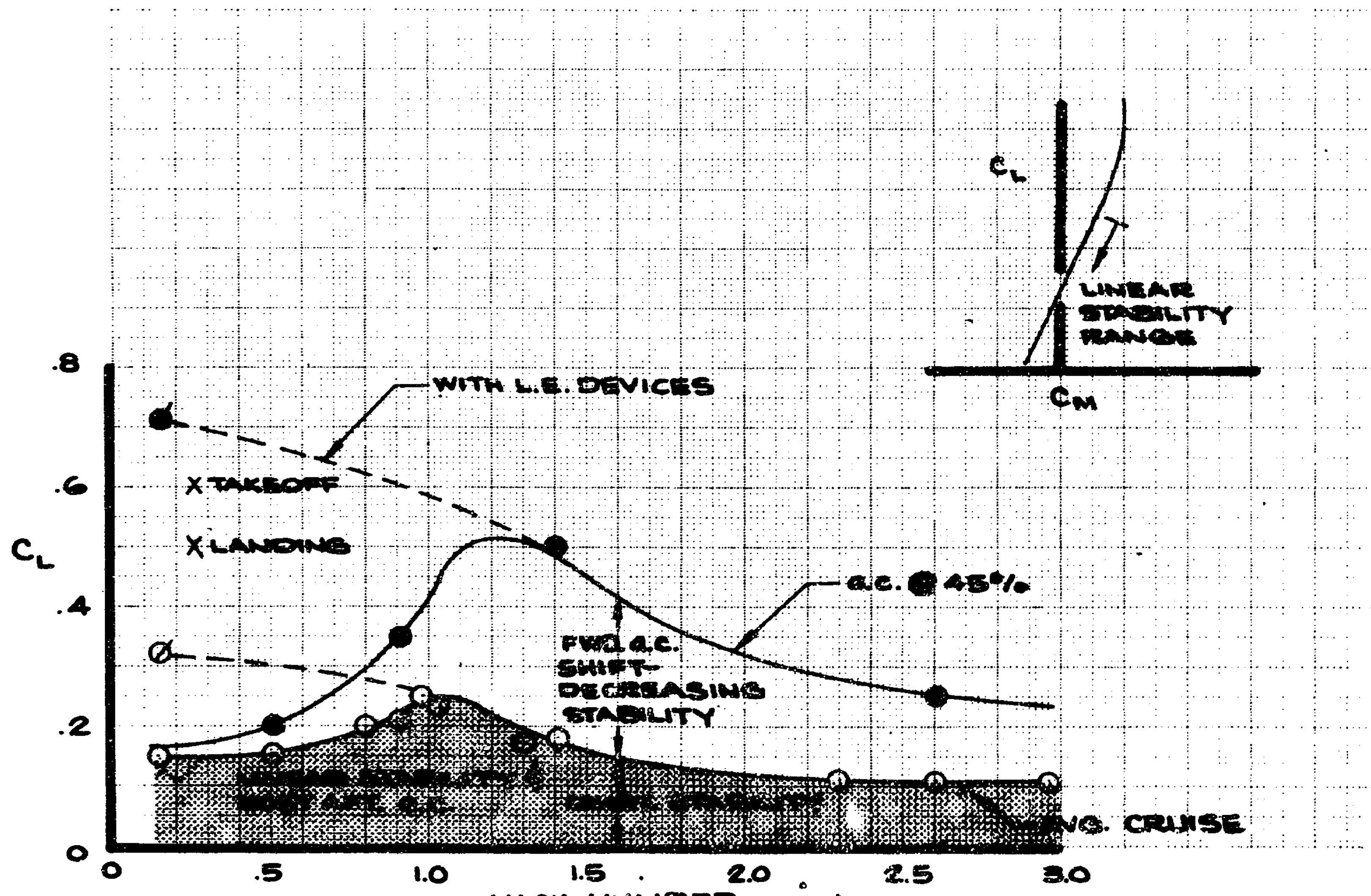


Fig. 3–35 Lift at Which Rigid A.C. Applies

linear stability range). Supersonic cruise is within the linear $\frac{dC_m}{dC_L}$ range while takeoff, landing, and most maneuvering flight conditions are in the non-linear range. The takeoff condition represents geometry limit attitude and results in the most forward a.c. location (49 percent MAC). Thus, the most aft CG condition (46 percent MAC) provides a 3 percent minimum static stability margin. It should be pointed out that takeoff and landing are executed with a high-lift canard which is retracted when wing flaps are up. No stability input is affected by the canard at airplane attitudes above 9 degrees (see Low Speed Trim and Control).

Maximum aeroelastic effects on a.c. location are about 9 percent MAC destabilizing (forward shift) and occur in supersonic maneuvering flight. This results from a theoretical analysis (linear aerodynamics) at constant q (dynamic pressure) varying load factor. Wing distortion and the accompanying a.c. shifts are proportional to total wing load changes --this change is largest for varying load factor (angle of attack). The greatest stability loss due to aerolasticity for the maneuver case occurs at maximum q (the dive placard) and results in 9 percent and 8 percent forward a.c. shift at $M = 1.2$ and $M = 2.7$, respectively. The corresponding result for maneuver at cruise is about 5 1/2 percent MAC (see Fig. 3-34). Aeroelastic stability losses for the constant load factor, speed varying case are assumed relatively small and therefore do not affect aft CG limit selection. The maximum wing aeroelastic effects at takeoff and landing are about 1 percent destabilizing. Thus, wing aeroelastic effects compromise the static stability (at aft CG) to a minimum of 2 percent maneuver margin at takeoff and 1 percent maneuver margin at $M = 2.7$. It should be noted that the $\frac{dC_m}{dC_L}$ slopes, for the maneuver neutral points shown, were measured at C_L for 1 g; at higher load factors the non-linear pitching moment characteristics result in reduced stability, and stick force lightening or reversal will occur unless forces are properly modified by the artificial feel system.

Analysis of thrust effects on static longitudinal stability was not accomplished; however, it is anticipated that these effects will be small.

b. Low Speed Trim and Control

The low-speed longitudinal trim and control system consists of three elevon panels and a high-lift retractable canard. The inboard elevon is used as a flap during takeoff and landing, at which time the canard is extended. All three elevons are available for trim and control at canard retracted flight conditions.

The basic, flaps-up, control characteristics (canard retracted) are shown in Fig. 3-36. Control is adequate at the forward CG limit, where pull-up is available to about 140 knots at a landing weight of 320,000 pounds ($\alpha = 21$ degrees). The pitch stability shown requires a wing leading-edge apex notch at the wing-body intersection; this notch is effective at airplane attitudes above 20 degrees.

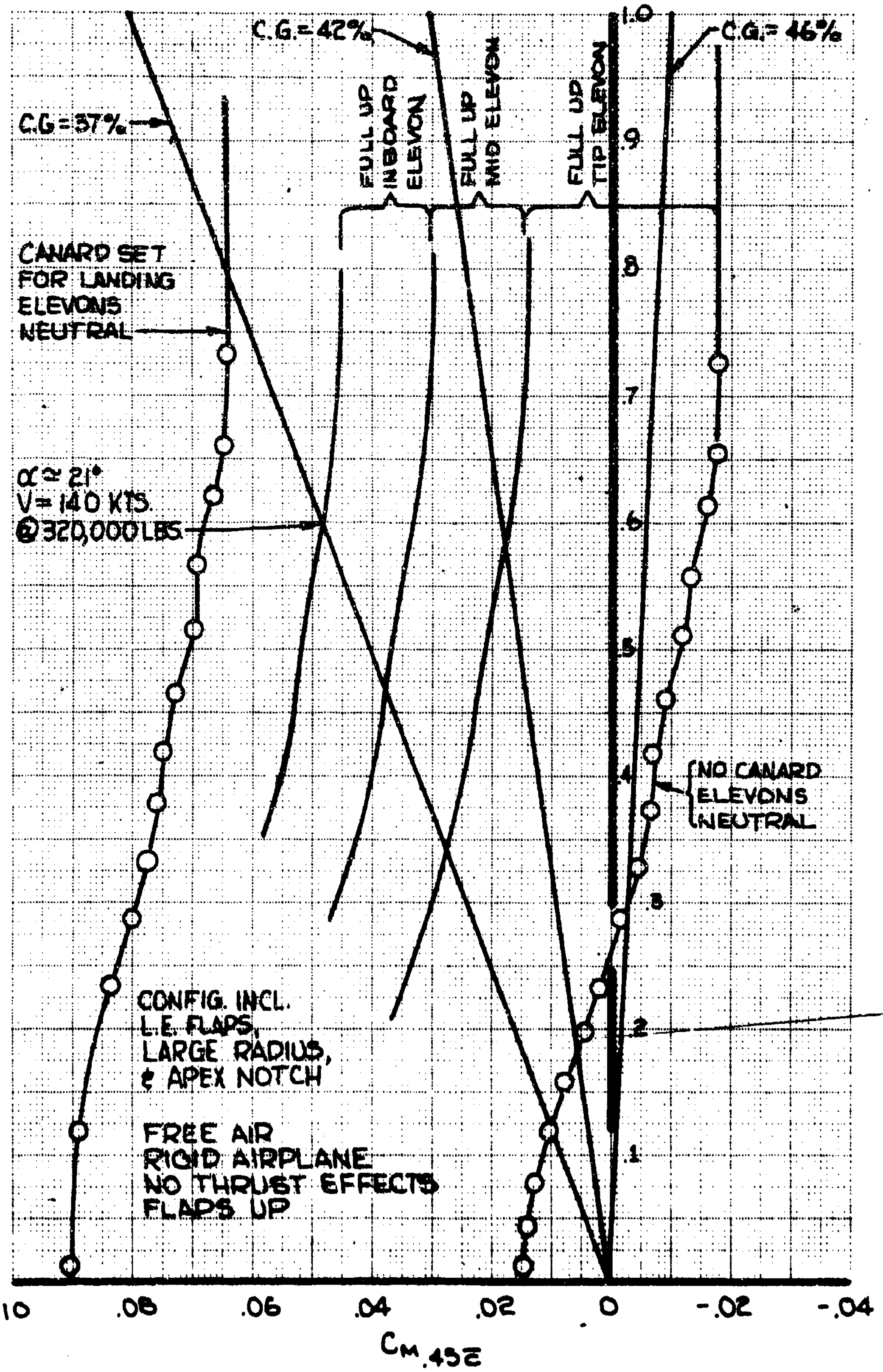


Fig. 3-36 Low Speed Trim and Control Characteristics

As noted in Fig. 3-36 the lift coefficients available at ground limited attitudes (Takeoff 12.9 degrees; landing 11.7 degrees) are very low. Trimmed lift at these conditions precludes the use of flaps. The canard is used to provide a positive C_{m_O} such that trailing edge flaps may be used; however, little or no stability change can be tolerated. Some stability loss will accrue at low C_L's, flaps down, because of the canard (below airplane attitudes of about 9 degrees). However, the canard is retracted in such a manner that supersonic stability and performance are not comprised. The sequencing of the canard-flap operation must not allow wing flaps down when the canard is not extended.

Canard size is dictated by the space limitations imposed to fully retract the canard in the body. This limitation results in a volume coefficient of 0.033 (exposed geometry). Canard performance is dictated by the flap moment input for landing, and requires $C_{L_{MAX}} = 2.5$. This performance is achieved by incorporating both leading and trailing-edge flaps. Estimated canard performance is shown in Fig. 3-36.

Utilizing the inboard elevon as a flap, the high-lift canard results in $C_{L_{LO}} = 0.60$ and $C_{L_{APP}} = 0.5$. The outboard elevons provide adequate control for these conditions.

Takeoff rotation requires a maximum control C_{m_O} input of 0.04 at the forward CG trimmed condition with flaps and canard set for takeoff. The outboard elevons provide about 0.05 C_{m_O} and thus takeoff rotation can be achieved at the forward CG limit of 37 percent MAC.

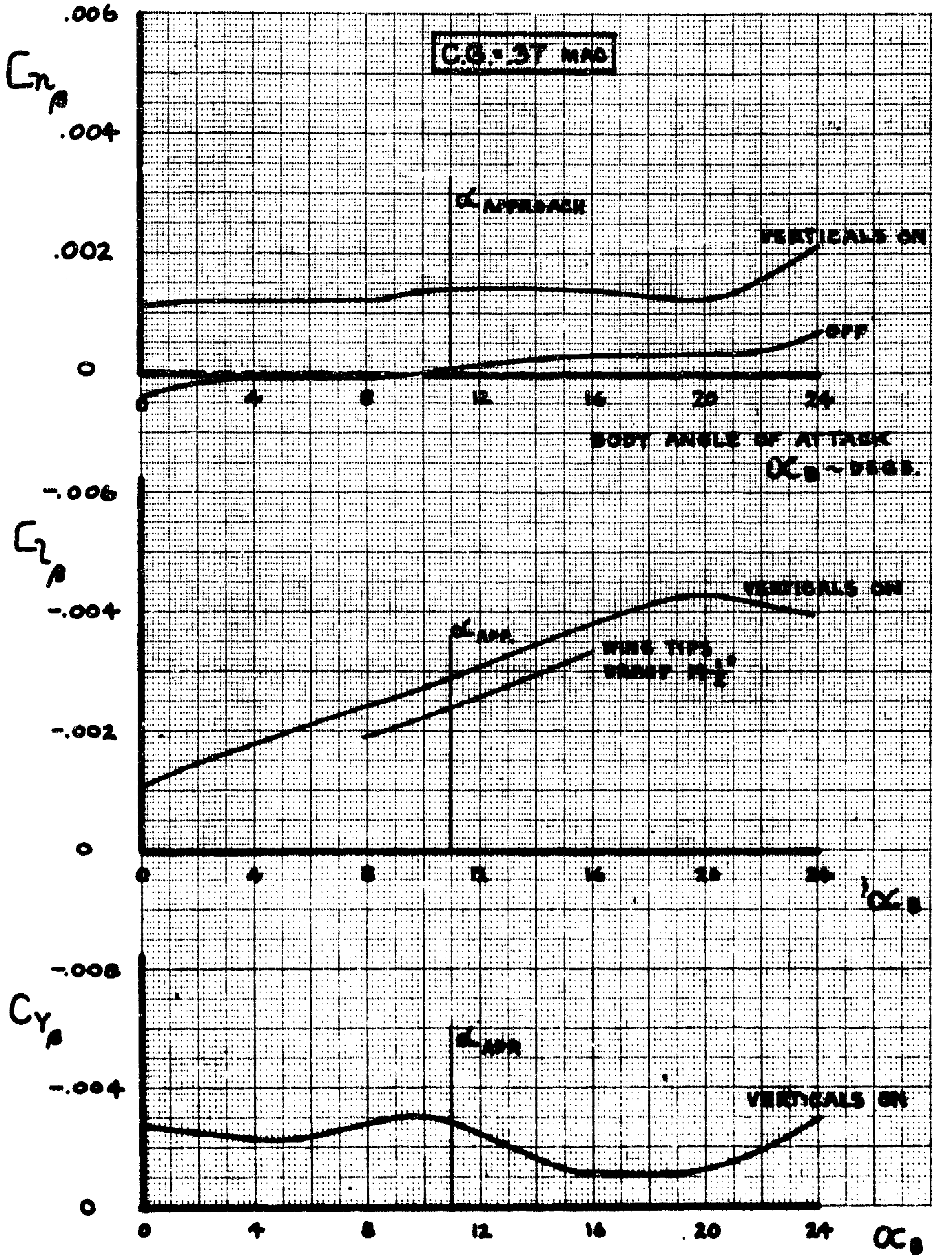
c. Dynamic Longitudinal Stability

No dynamic stability analysis has been made for the SCAT 15F-B7; however, based on previous analysis (NASA SCAT Contract, etc.) it appears from the configuration arrangement and inertia distribution that longitudinal handling qualities without stability augmentation will be characterized by sluggish response at low speed and supersonic cruise conditions, and poor damping at cruise. These characteristics are typical for all SST configurations investigated to date, and are slightly worse for tailless airplanes. A pitch response-quickening ($\dot{\theta}$ feedback) augmentation system is probably required for satisfactory longitudinal handling qualities at all flight conditions.

3.3.4.2 Lateral-Directional

a. Static Lateral-Directional Stability and Control

The static sideslip derivatives for low-speed approach are plotted in Fig. 3-37. Directional stability (C_{n_β}) is satisfactorily positive and nearly constant up to angles of attack of 20 degrees; beyond which stability increases. Dihedral effect (C_{l_β}) characteristically reflects the wing sweep influence and is large at approach angles of attack. The effect of wing tip anhedral is shown as an attempt to reduce the magnitude of C_{l_β} to improve low speed handling qualities and cross-wind landing capability.



NOTE: TAIL (VERTICAL) $\bar{V}_{V_{TOTAL}}$ = 0.047 (MEASURED TO .40 MAC)

Fig. 3–37 Estimated Lateral–Directional Static Derivatives at Approach

The low-speed roll control derivatives plotted in Fig. 3-38 show the contribution of the three elevon panels e_3, e_2, e_1 to roll control, and also an additional roll control inboard spoiler which would be used as a dive brake and landing brake. The estimated maximum steady-state roll capability at landing approach conditions is plotted in Fig. 3-39 for zero sideslip conditions. Adequate roll rate ability is provided when all roll controls are operative. The roll rate capability might prove to be marginal at speeds less than the normal approach speed of 153 knots.

The maximum roll rate capability with sideslip at approach is plotted in Fig. 3-40. The severe limitations of sideslip attainable is immediately apparent in view of the fact that roll control in one direction is completely lost at a trimmed angle of sideslip of 10 degrees at 153 knots approach speed, and at 12.6 degrees at 175 knots approach speed. This results primarily from the large dihedral effect (C_{l_β}) inherent in this highly-swept configuration. Drooping the wing tips 14 1/2 degrees (maximum acceptable for ground clearance) is seen to provide a small improvement in the sideslip capability, and therefore has been incorporated in the configuration.

Providing a 15 degrees-per-second roll rate capability (a practical minimum) limits the corsswind landing capability to 90 degree crosswinds of only 13 knots magnitude at the nominal approach speed of 153 knots. For this reason crosswind landing gear has been incorporated to provide the capability to land in 90 degree, 30 knot crosswinds. The special gear eliminates any need for a "decrab" maneuver and the associated large lateral control requirements.

The rudder capability to hold an adverse engine failure at normal gross weight takeoff is presented in Fig. 3-41, which indicates that at the normal take-off CG of 42 percent MAC, full rudder at 30 degree deflection will hold the adverse yawing moment at speeds above 148.5 knots. The V_1 decision speed is normally at 150 knots and $V_{Rotation}$ at 157.5 knots. This design ensures that, for engine failures occurring above V_1 speed and below $V_{Rotation}$, the adverse yaw can be trimmed with the rudder instead of with nose-wheel steering or differential braking. Provision would be made to ensure that lateral control capability is not exceeded by the large rudder power available.

The static lateral-directional derivatives at Mach 2.7 are plotted in Fig. 3-42 for a normal cruise CG of 42 percent.

No flexible effects are presented, but it is not expected that directional stability (C_{n_β}) would be reduced by more than 30 percent at the most critical conditions, thus retaining acceptable characteristics.

No cruise engine-out data are available and no dynamic analyses have been made for this condition.

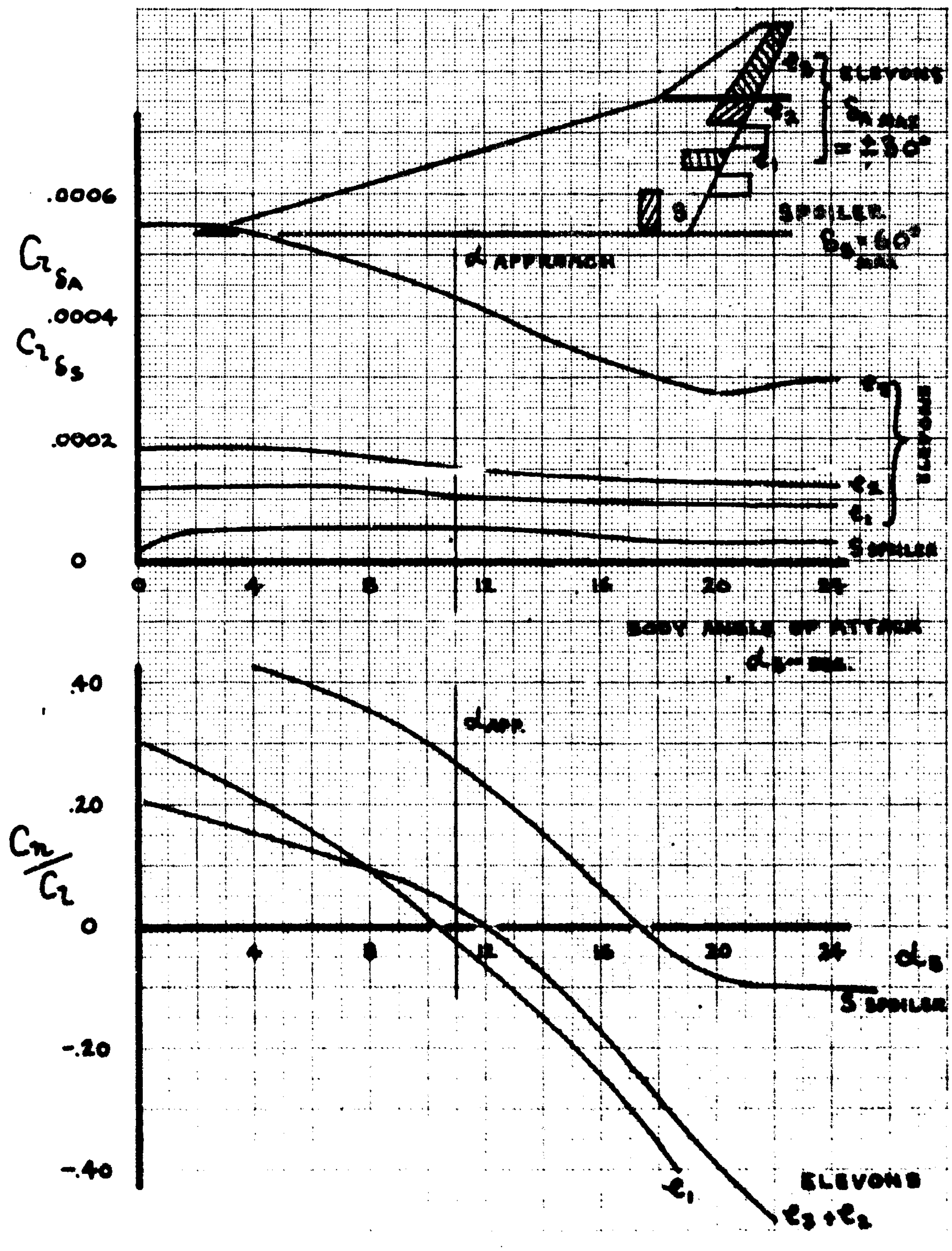


Fig. 3-38 Estimated Lateral Control Characteristics at Approach

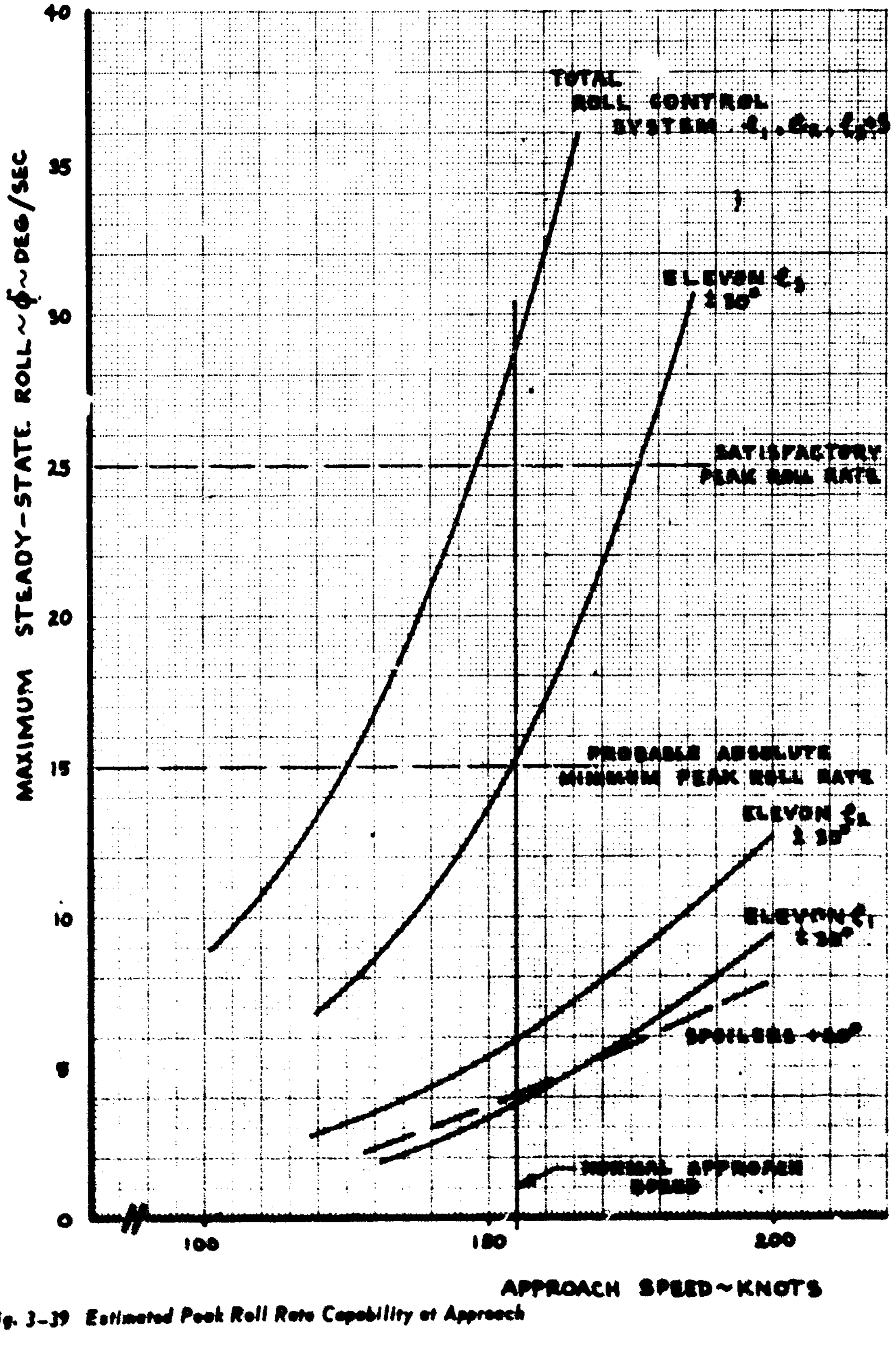


Fig. 3-39 Estimated Peak Roll Rate Capability at Approach

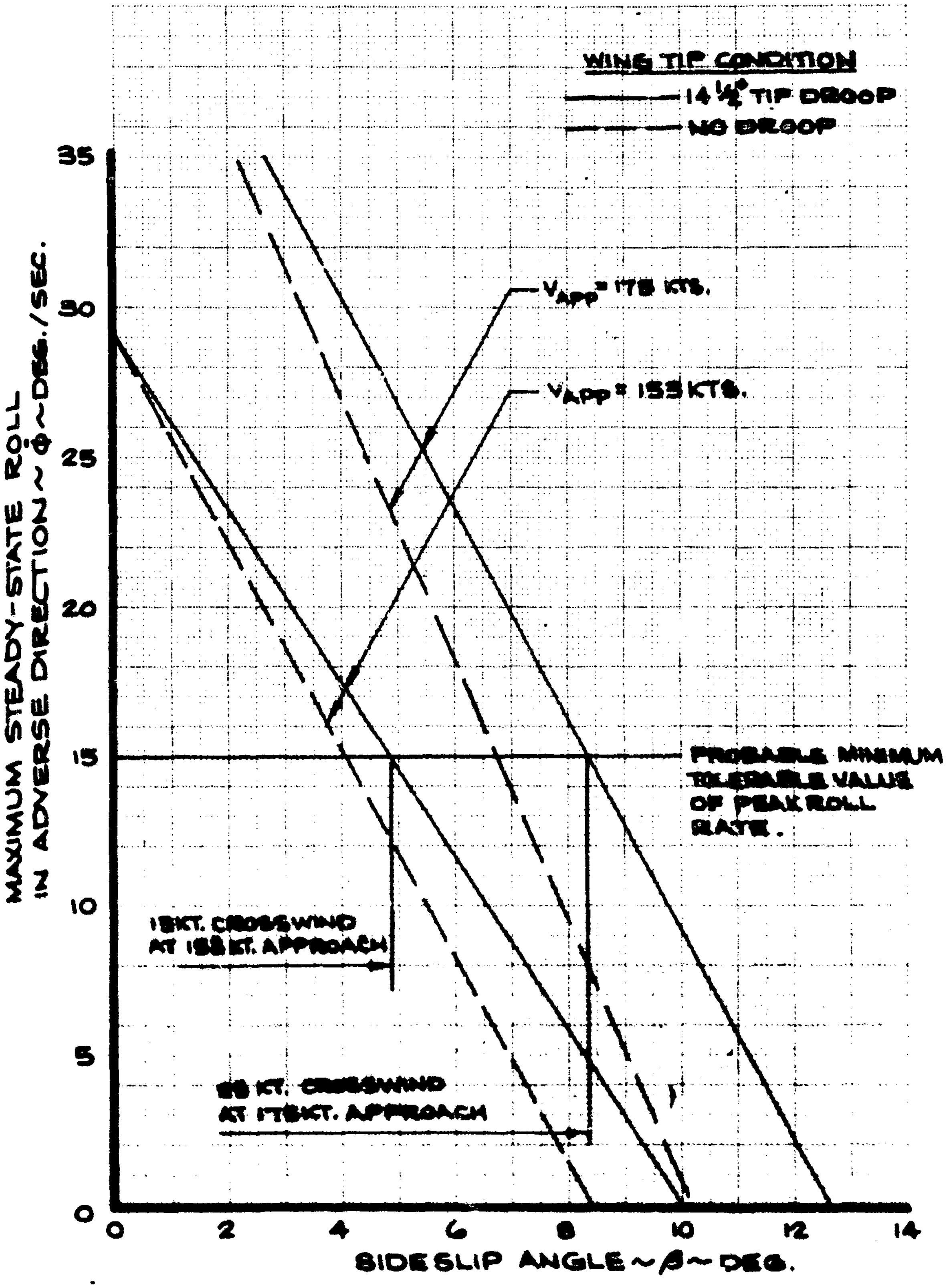


Fig. 3-40 Effect of Sideslip on Peak Roll Rate Capability at Approach

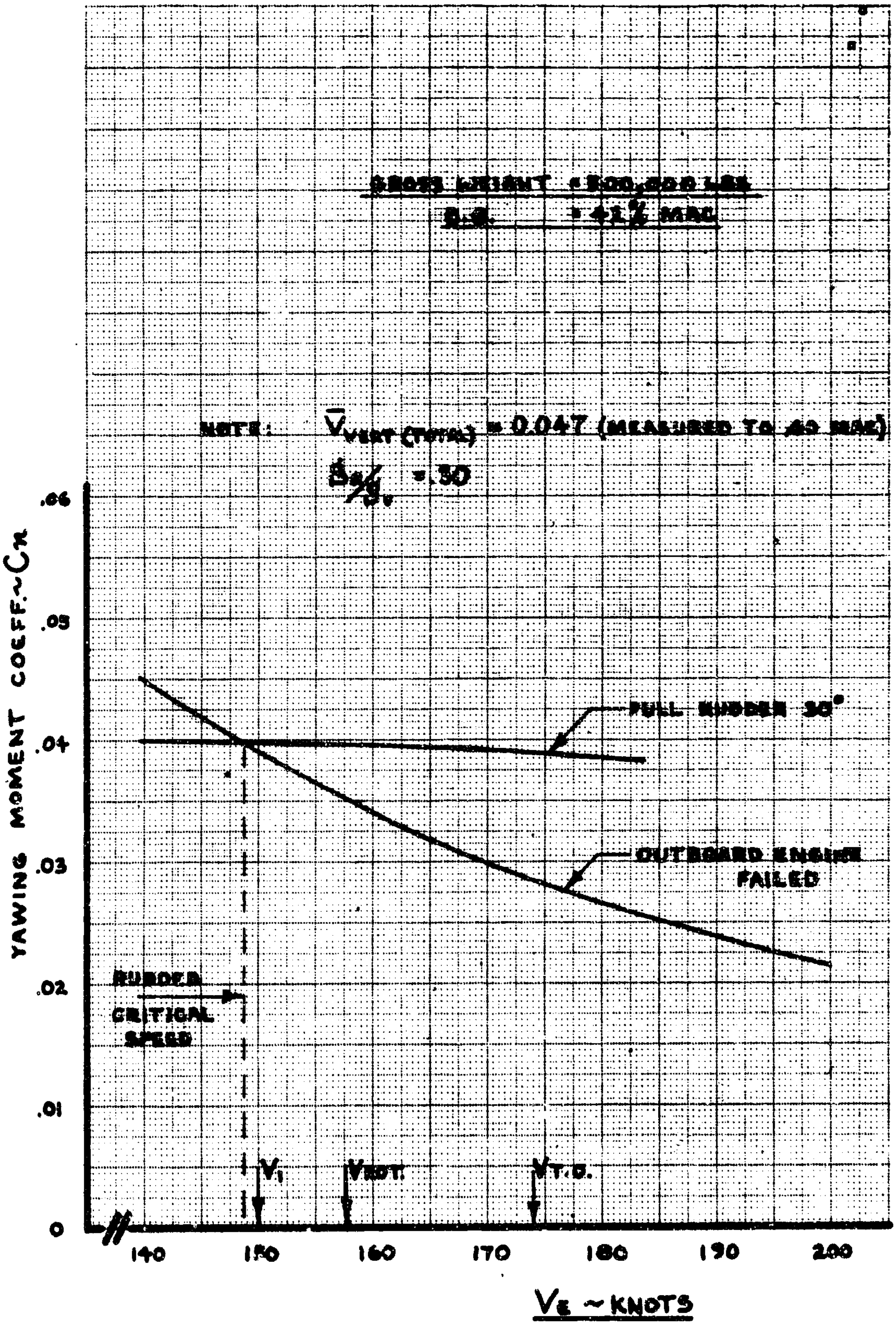


Fig. 3-41 Rudder Capability to Balance Critical Engine Failure at Takeoff

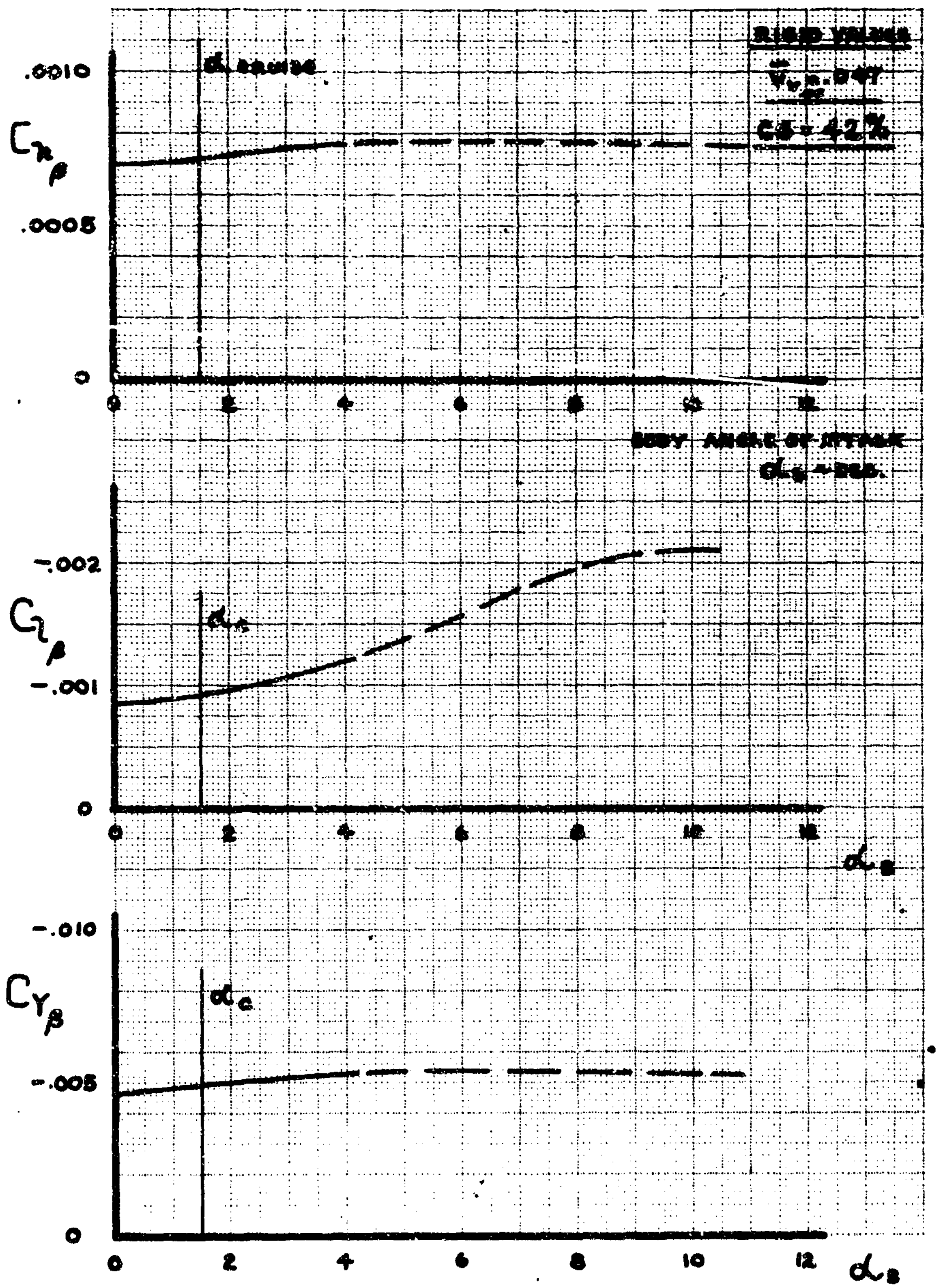


Fig. 3–42 Estimated Lateral – Directional Static Derivatives at M = 2.7

b. Dynamic Lateral-Directional Stability

The Dutch roll characteristics of the unaugmented SCAT 15F-B7 airplane were calculated for the following flight conditions:

1. Landing Approach
   W = 318,000 pounds, V = 153 knots
   SL, STD Day
   Undamped natural frequency W_n = 0.869 RAD/SEC
   Damping Ratio ζ_d = .215
   ϕ/β = 3.47
   ϕ/V_c = 0.783

2. Supersonic Cruise
   W = 441,000 pounds, M = 2.7
   Altitude = 66,000
   STD Day
   Undamped natural frequency W_n = 0.741 RAD/SEC
   Damping Ratio ζ_d = 0.0083
   ϕ/β = 10.29
   ϕ/V_c = 0.861

Correlation of the undamped natural frequencies and damping ratios with the requirements of NADC-ED-6282 (MIL-F-8785-ASG) shows the landing condition marginally acceptable. The cruise condition falls below the minimum requirements. It is probable that a triplicated yaw damper system will be required to assure acceptable handling qualities at all flight conditions, and to eliminate the necessity for aborting a flight when a single yaw damper failure occurs sometime after take-off.

The unaugmented Dutch roll characteristics of the SCAT 15F-B7 airplane (Fig. 3-43) were calculated by means of a small disturbance solution of the equations of motion. The static lateral-directional stability derivatives were determined from NASA wind tunnel data. The dynamic lateral-directional stability derivatives were estimated from data presented in the USAF Stability and Control Handbook (DATCOM), from the static stability derivates and from NASA SCAT 14 data. The derivatives are listed in Tables 3-F and 3-G.

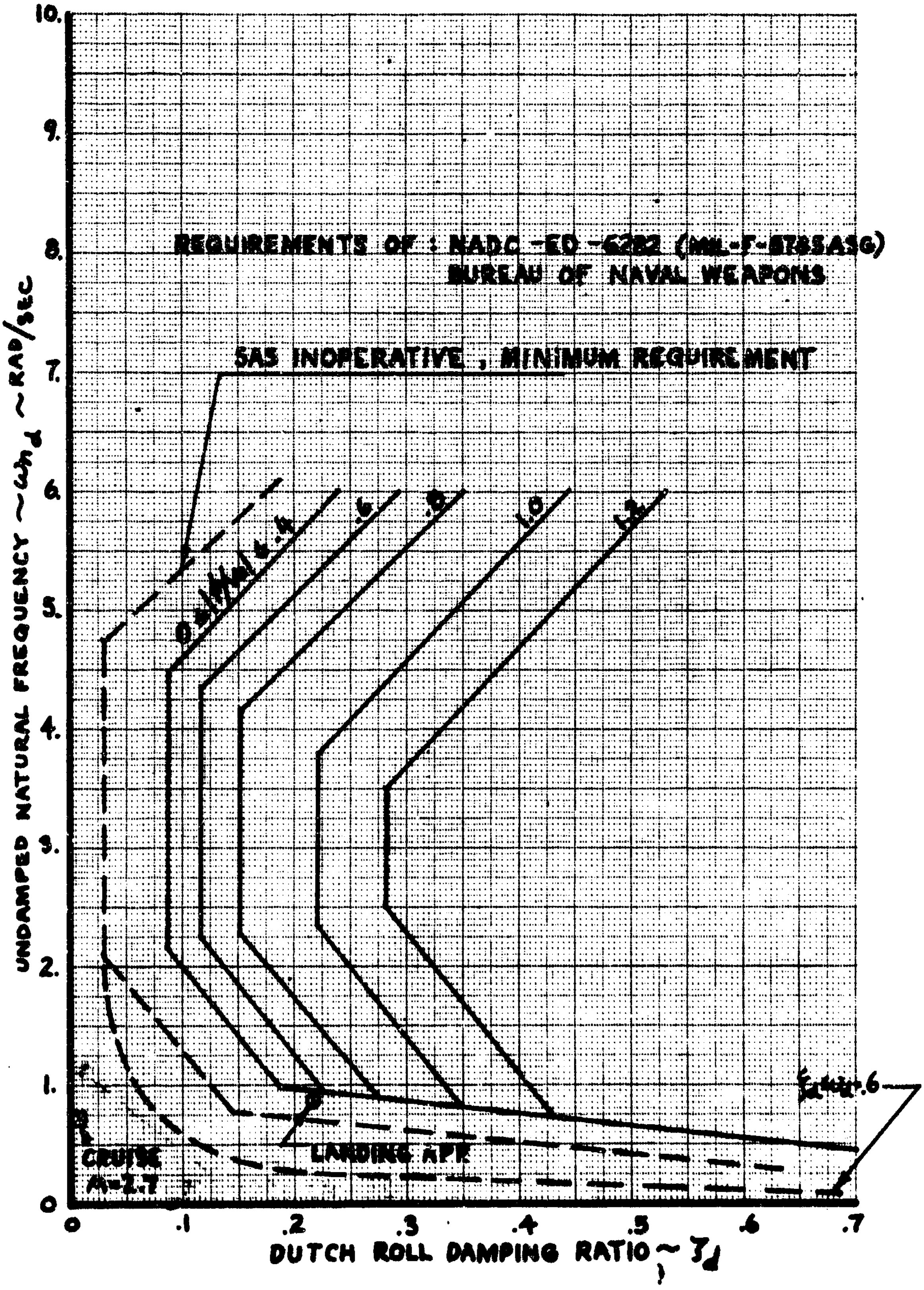


Fig. 3–43 Unaugmented Dutch Roll Characteristics

Table 3-F Airplane Stability Derivatives for the SCAT 15F-B7

Supersonic Cruise

ITEM	SYMBOL	VALUE	DIMENSION
Weight	W	441000	LBS.
Altitude	h	66000	FT.
Reference Geometry L.E. = 74°			
Wing Area	Sw	8000	$FT.^2$
Wing Span	b	105	FT.
Wing MAC	$\bar{c}$	98	FT.
Moments of Inertia in Body Axes.	I_{xx}	$4.3 \cdot 10^6$	SLUG $FT.^2$
	I_{yy}	29.4×10^6	SLUG $FT.^2$
	I_{zz}	$33.7 \cdot 10^6$	SLUG $FT.^2$
	I_{xz}	0.	SLUG $FT.^2$
Inclination of Stability x Axis from Body Reference x Axis Positive Down	ϵ_s	1.5	DEG.
Equivalent Airspeed	V_e	405	KTS.
True Air Speed	V_T	2610	FT./SEC.
Airplane Trimmed Lift Coefficient ($C_L = W/q\ S_W$)	C_L	.0972	
Angle of Attack at Trim	α_{TRIM}	1.5	DEG.
Airplane Lift Curve Slope	$C_{L\alpha}$	1.55	$RAD.^{-1}$
Center of Gravity Position	CG	.42	% $\bar{c}$
Aerodynamic Time (Lat.-Dir.)	$b/2V_T$	.02	SEC.
Static Directional Stability	$C_{n\beta}$	.0268	$RAD.^{-1}$
Effective Dihedral	$C_{\ell\beta}$	-.0545	$RAD.^{-1}$
Side Force Due to Sideslip	$C_{y\beta}$	-.286	$RAD.^{-1}$
Yaw Damping Due to Yaw Rate	C_{n_r}	-.18	$RAD.^{-1}$
Roll Due to Yaw Rate	C_{ℓ_r}	.0012	$RAD.^{-1}$
Side Force Due to Yaw Rate	C_{y_r}	.018	$RAD.^{-1}$
Yaw Due to Roll Rate	C_{n_p}	-.0044	$RAD.^{-1}$
Roll Damping Due to Roll Rate	C_{ℓ_p}	-.12	$RAD.^{-1}$
Side Force Due to Roll Rate	C_{y_p}	.0262	$RAD.^{-1}$

Table 3-G Airplane Stability Derivatives for the SCAT 15F-B7

Landing Approach

ITEM	SYMBOL	VALUE	DIMENSIONS
Weight	W	318000	LBS.
Altitude	h	SL	FT.
Reference Geometry L.E. = 74°			
Wing Area	Sw	8000	$FT.^2$
Wing Span	b	105	FT.
Wing MAC	$\bar{c}$	98	FT.
Moments of Inertia in Body Axes	I_{xx}	$3.0x10^6$	$SLUG\ FT.^2$
	I_{yy}	$26.9x10^6$	$SLUG\ FT.^2$
	I_{zz}	$30.5x10^6$	$SLUG\ FT.^2$
	I_{xz}	0	$SLUG\ FT.^2$
Inclination of Stability x Axis from Body Reference x Axis Positive Down	ϵ_s	6	DEG.
Equivalent Airspeed	V_e	153	KTS.
True Air Speed	V_T	254	FT./SEC.
Airplane Trimmed Lift Coefficient ($C_L = W/q\ S_W$)	C_L	.46	
Angle of Attack at Trim	α_{TRIM}	11.	DEG.
Airplane Lift Curve Slope	$C_{L\alpha}$	1.95	$RAD.^{-1}$
Center of Gravity Position	CG	.37	% $\bar{c}$
Aerodynamic Time (Lat.-Dir.)	$b/2V_T$	.2067	SEC.
Static Directional Stability	$C_{n\beta}$	.086	$RAD.^{-1}$
Effective Dihedral	$C_{l\beta}$	-.166	$RAD.^{-1}$
Side Force Due to Sideslip	$C_{y\beta}$	-.115	$RAD.^{-1}$
Yaw Damping Due to Yaw Rate	C_{n_r}	-.149	$RAD.^{-1}$
Roll Due to Yaw Rate	C_{l_r}	.156	$RAD.^{-1}$
Side Force Due to Yaw Rate	C_{y_r}	.275	$RAD.^{-1}$
Yaw Due to Roll Rate	C_{n_p}	-.0136	$RAD.^{-1}$
Roll Damping Due to Roll Rate	C_{l_p}	-.227	$RAD.^{-1}$
Side Force Due to Roll Rate	C_{y_p}	.780	$RAD.^{-1}$

4.0 CONFIGURATION

Design objectives for the SCAT 15-F-220 included a capacity for 220 passengers. However, the available data indicated that the mixed class (10 percent first class and 90 tourist) interior arrangement would accommodate no more than 198 passengers (SCAT 15F-B1, Fig. 4-1).

The body of the airplane was lengthened and the cross-section enlarged in order to accommodate a 43,000 pound payload (Boeing SCAT 15F-B2, Fig. 4-2). A complete performance evaluation was made of this model.

A number of configurations were studied to obtain improved low-speed performance. Mid-chord flaps, conventional aft stabilizer, low speed canard, boundary layer control, etc. were investigated. Table 4-A lists the various configurations for which three-view drawings were prepared. Only the configurations of major interest are discussed in this report.

SCAT 15F-B7 with a canard was found to most nearly meet the design objectives. The configuration is shown and described in Section 4.1.

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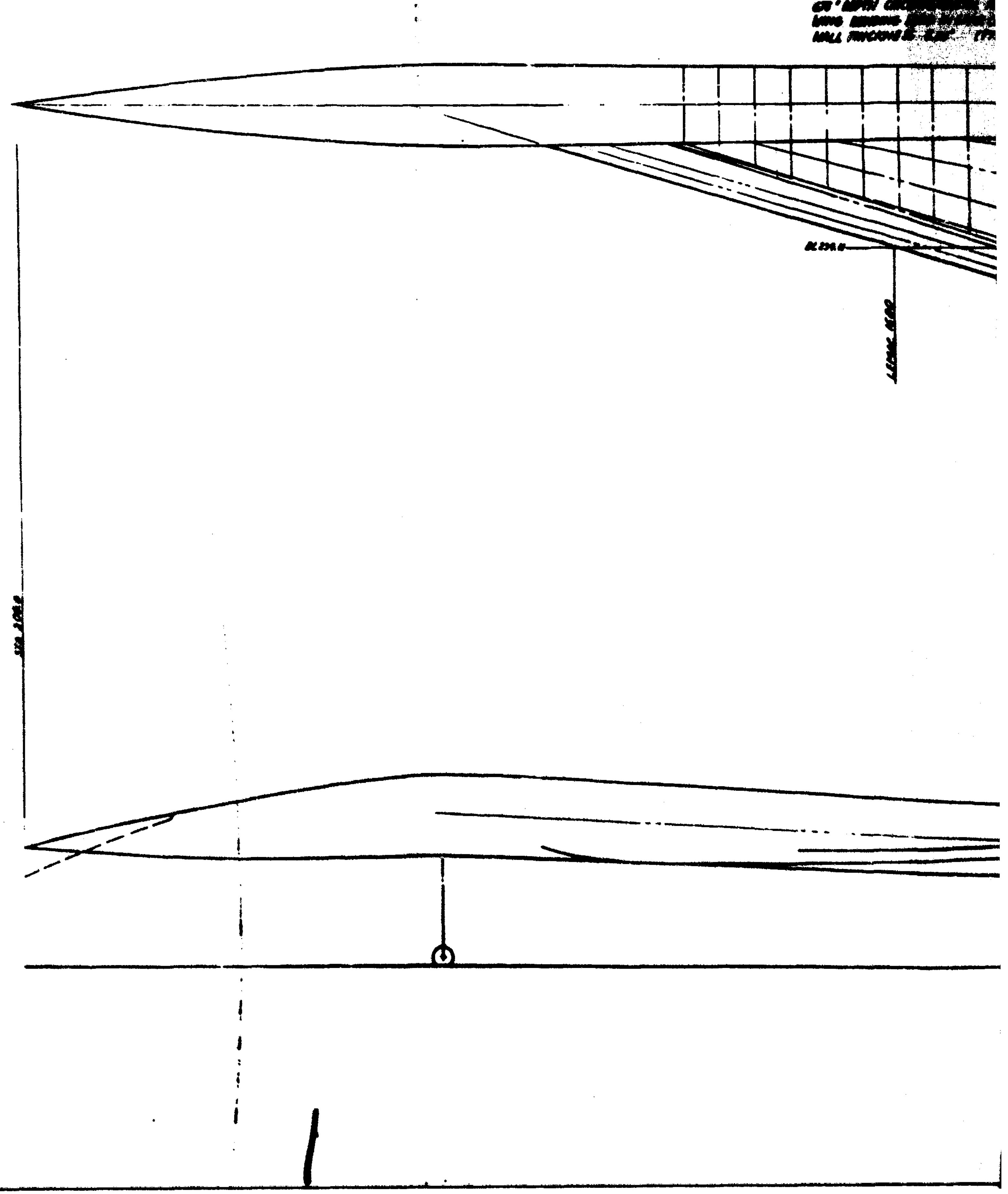

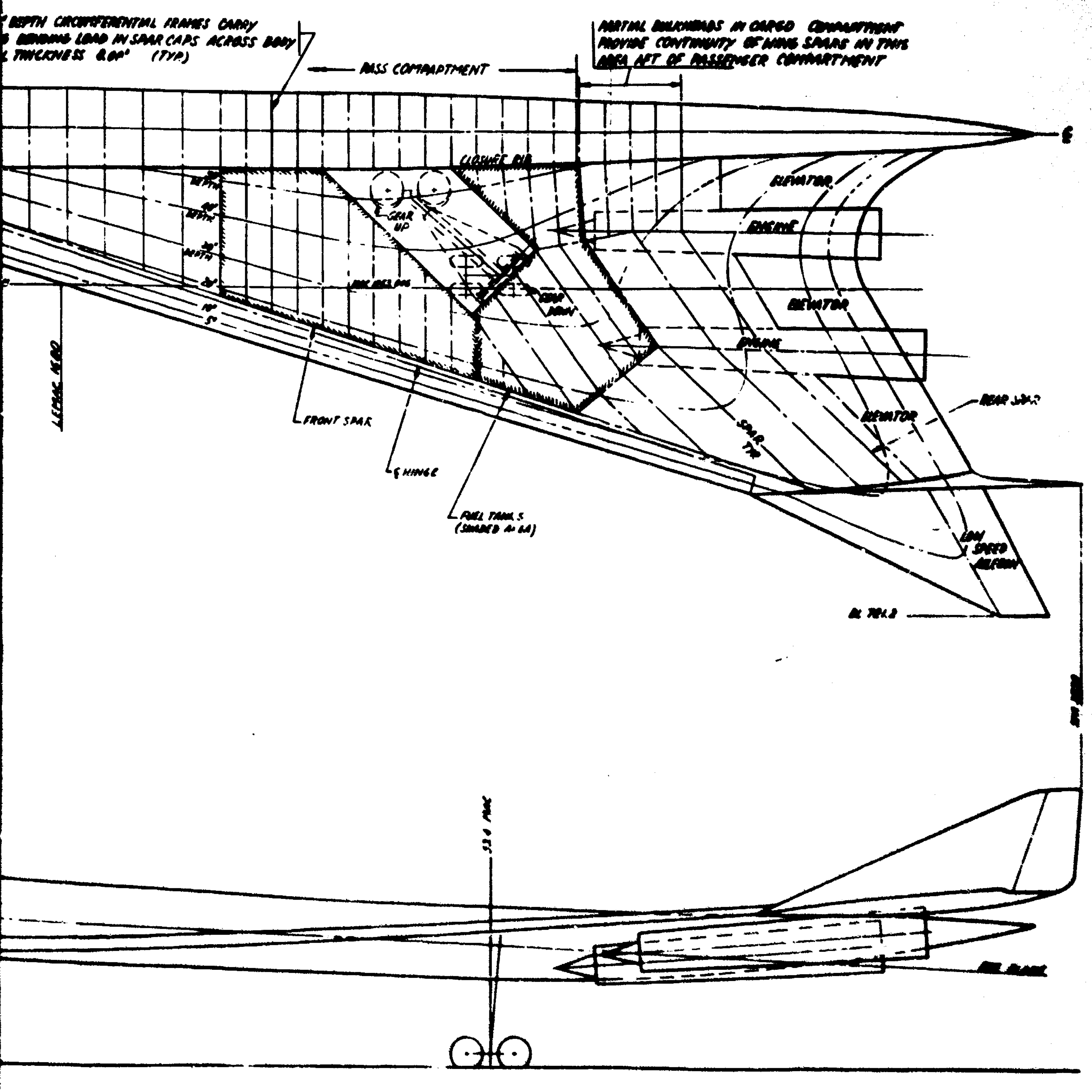

Fig. 4-1 Modified NASA 15F-220 - SCAT 15F-81

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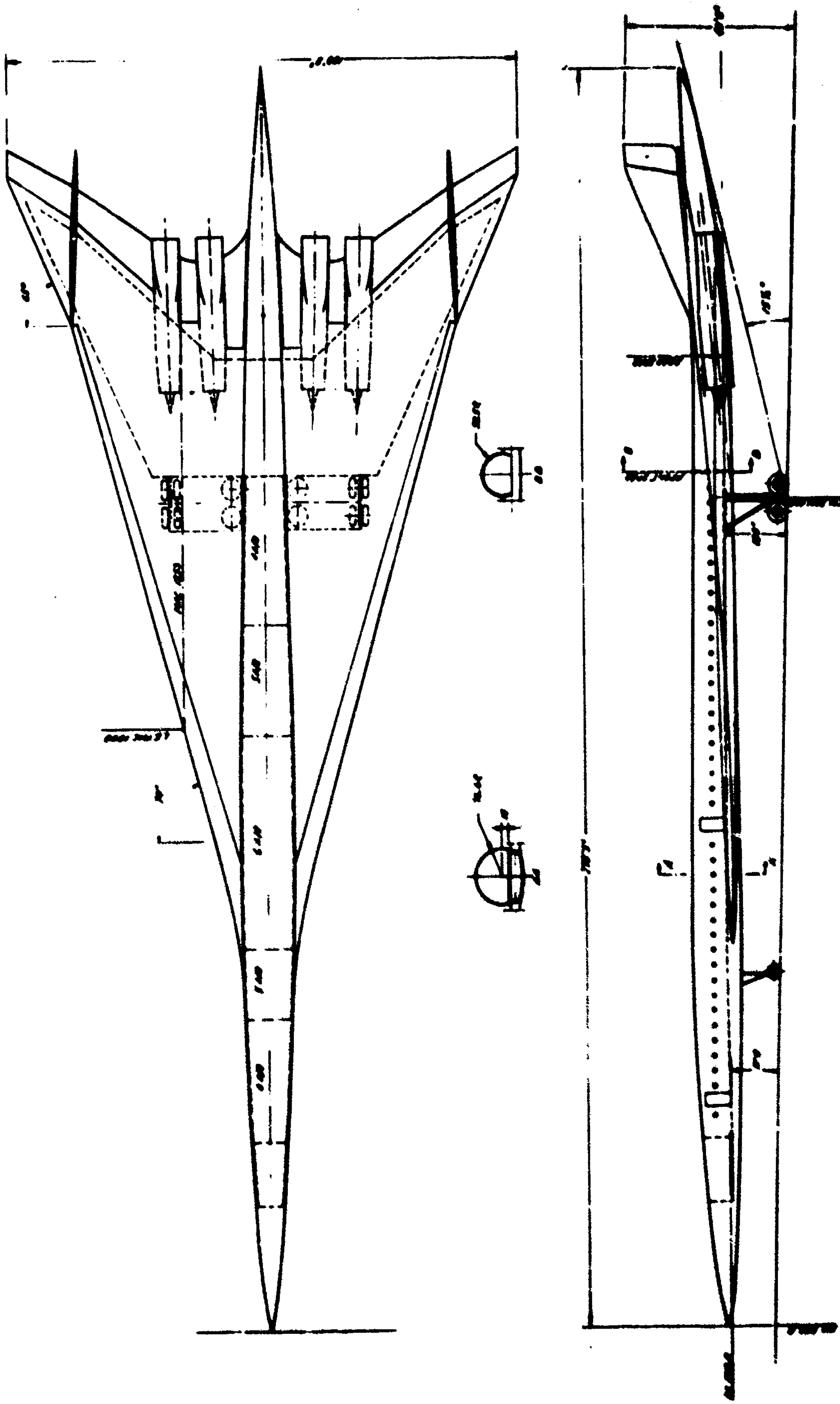


Fig. 4-2 Modified NASA 15F-220 – SCAT 15F-B2

Table 4-A SCAT 15F Configurations

SCAT 15F-	B1	B2	B3	B4	B5	B6	B7
GROSS WEIGHT	430,000	430,000	430,000	500,000	500,000	430,000	500,000
PAYLOAD	39,600	43,000	41,000	43,000	43,000	43,000	43,000
FUEL	180,000	176,660	185,000	228,000	223,000	182,900	226,500
O.E.W. [1]	210,400	[2] 210,340	204,000	229,000	234,000	204,100	[2] 230,500
WING AREA	9150	9150	6450	7500	10272	7000	8000
VERT. STAB.	305 each	305 each	215 each	289 each	389 each	233 each	340 each
CANARD	None	None	Fixed	None	Retractable	Retractable	Retractable
CANARD AREA	----	----	275	----	200	200	200
HORIZ. STAB.	None	None	None	880	None	None	None

Remarks: [1] 1st order approximations except [2] which are analyzed.

4.1 CONFIGURATION DESCRIPTION

The geometric data required to determine aerodynamic characteristics of the configuration are presented in the following figures and tables.

Table 4-B Wing Geometry

Reference Wing Area, $ft.^2$	8000 $ft.^2$
Reference MAC Ft.	97'10"
Leading Edge Sweep:	
Inboard of Vertical Stabilizer	74.0°
Outboard of Vertical Stabilizer	65.210°
Sweep at .25 Chord	70°
Dihedral:	
Inboard of Vertical Stabilizer	0°
Outboard of Vertical Stabilizer	-14.5°
Angle of Incidence of Wing Reference Plane to Fuselage Reference Plane	-4.667°
Angle of Incidence of Root Chord to Fuselage Reference Line	-0.50°
Angle of Incidence at Vertical Stabilizer	-5.45°
Wing Span - Ft.	112'2"

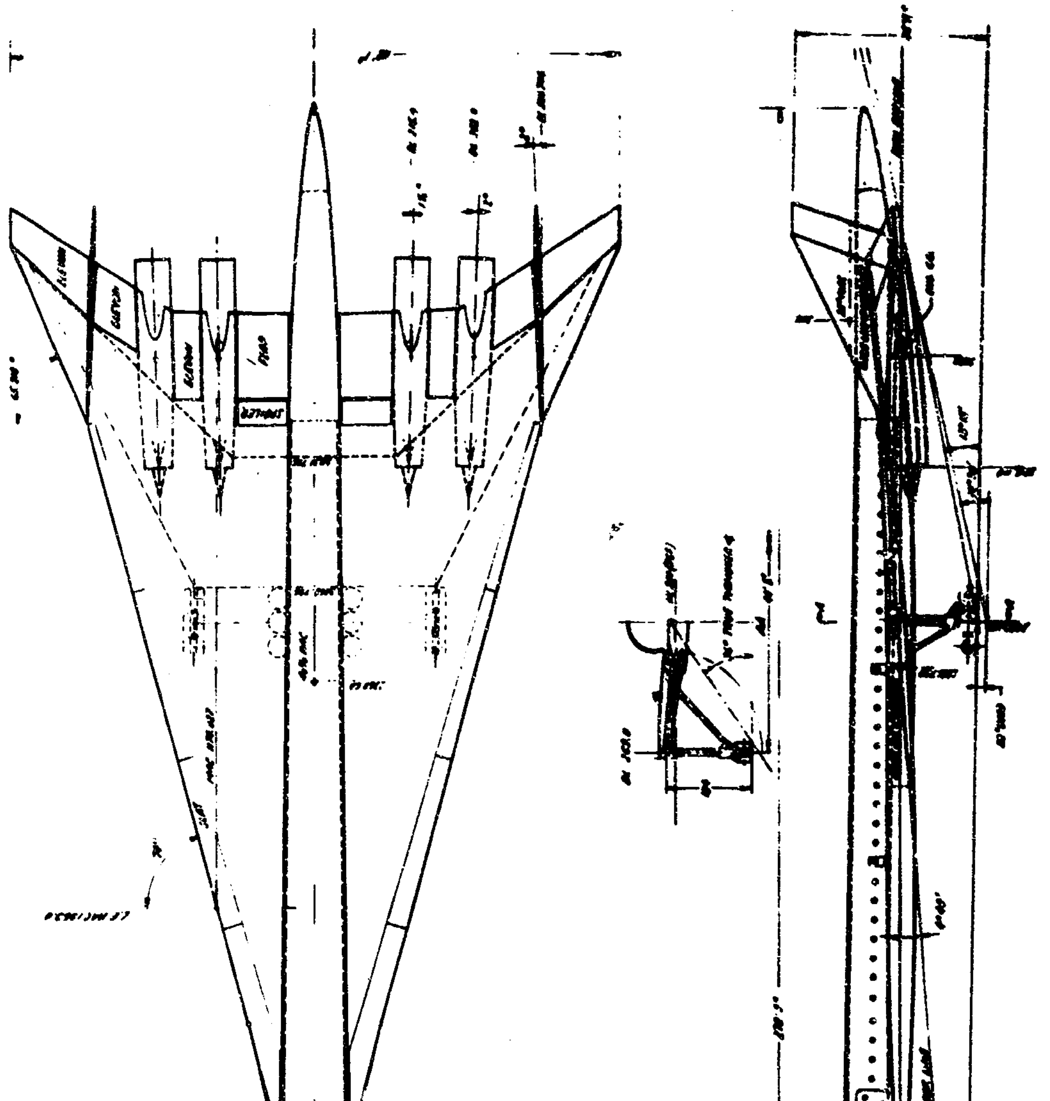
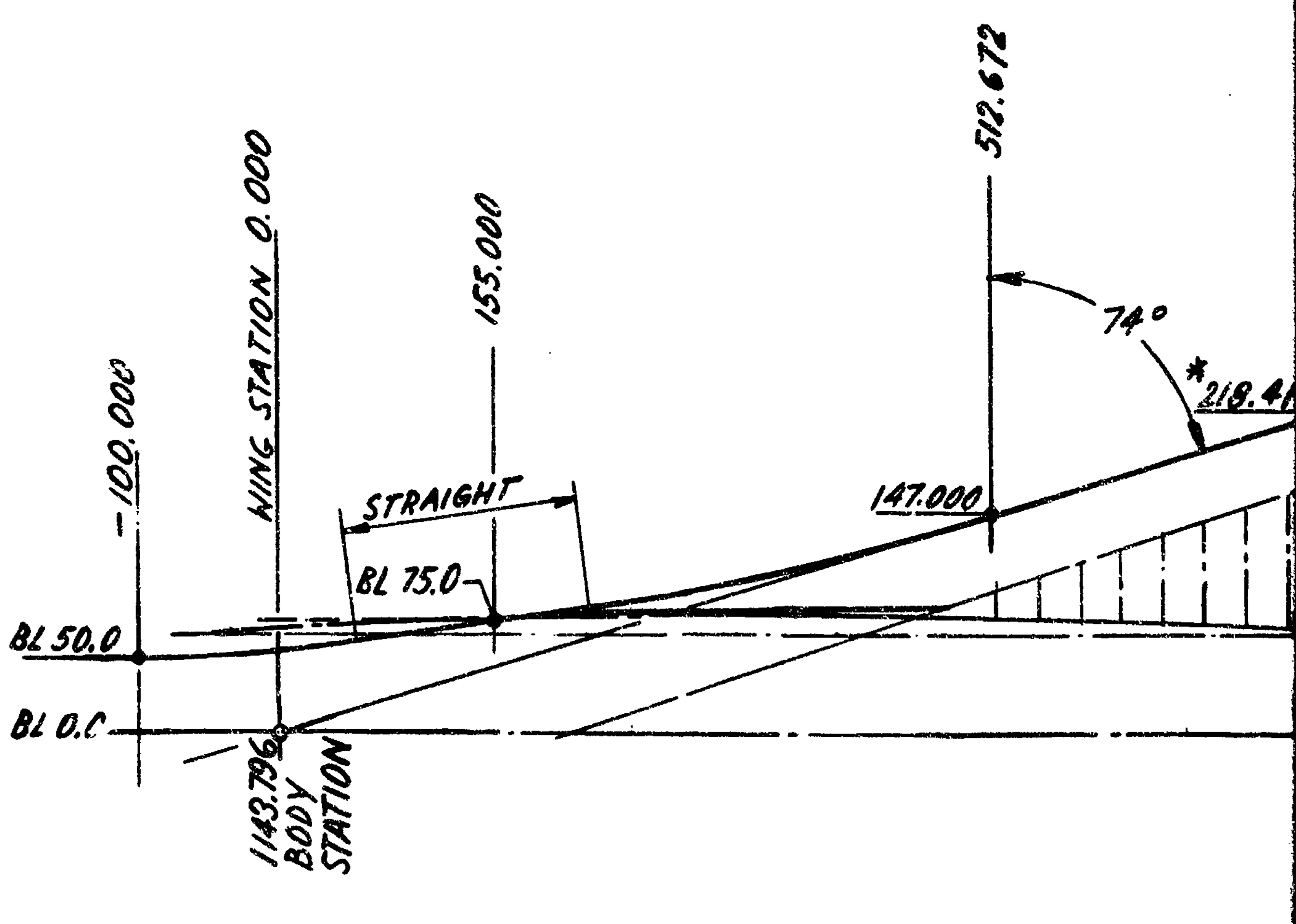


Fig. 4-3 Modified NASA 15F-220 – SCAT 15F-B7

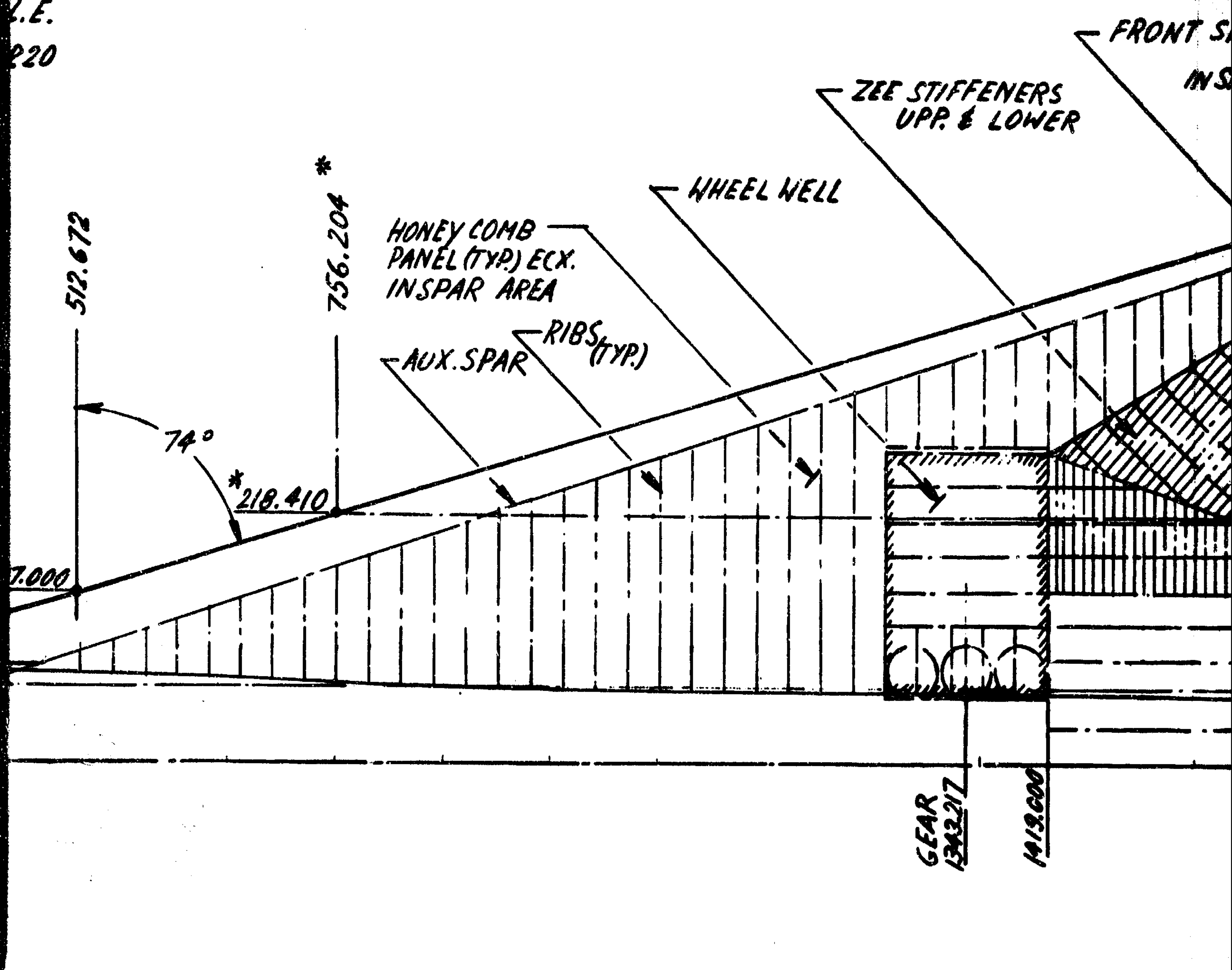
WING AREA WITHOUT T.E. FILLET : 8000 FT^2
TOTAL WING AREA 8395.976 FT^2
$\left.\begin{array}{l} AR = 1.572 \\ \lambda = .044 \end{array}\right\}$ BASED ON 8000 FT^2

<u>NOTE</u>: POINT MARKED* IS NOT ON L.E.
t/c DISTRIBUTION SAME AS 15F-220



3000 FT²

L.E.
220



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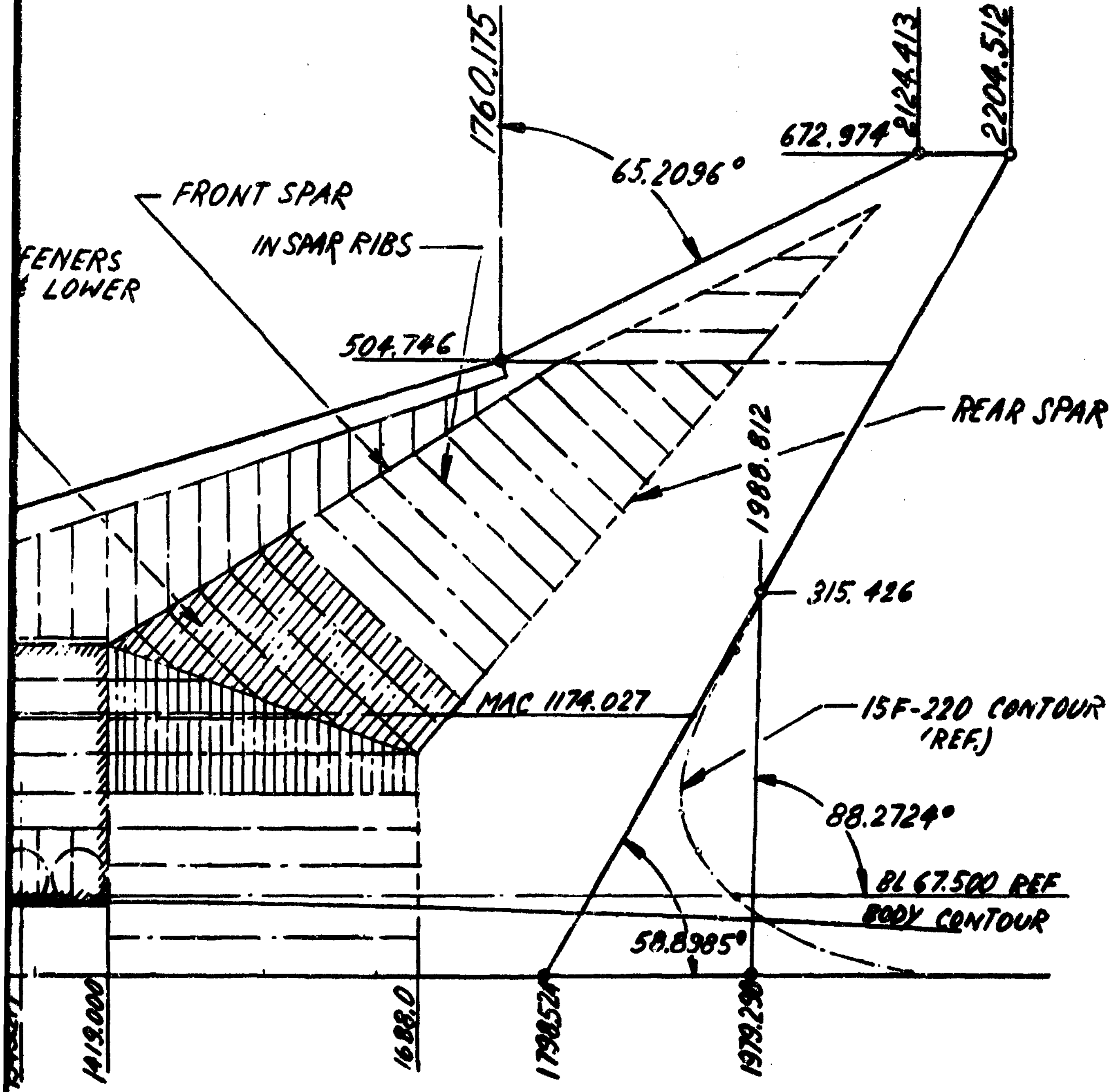

Fig. 4-4 Wing Details

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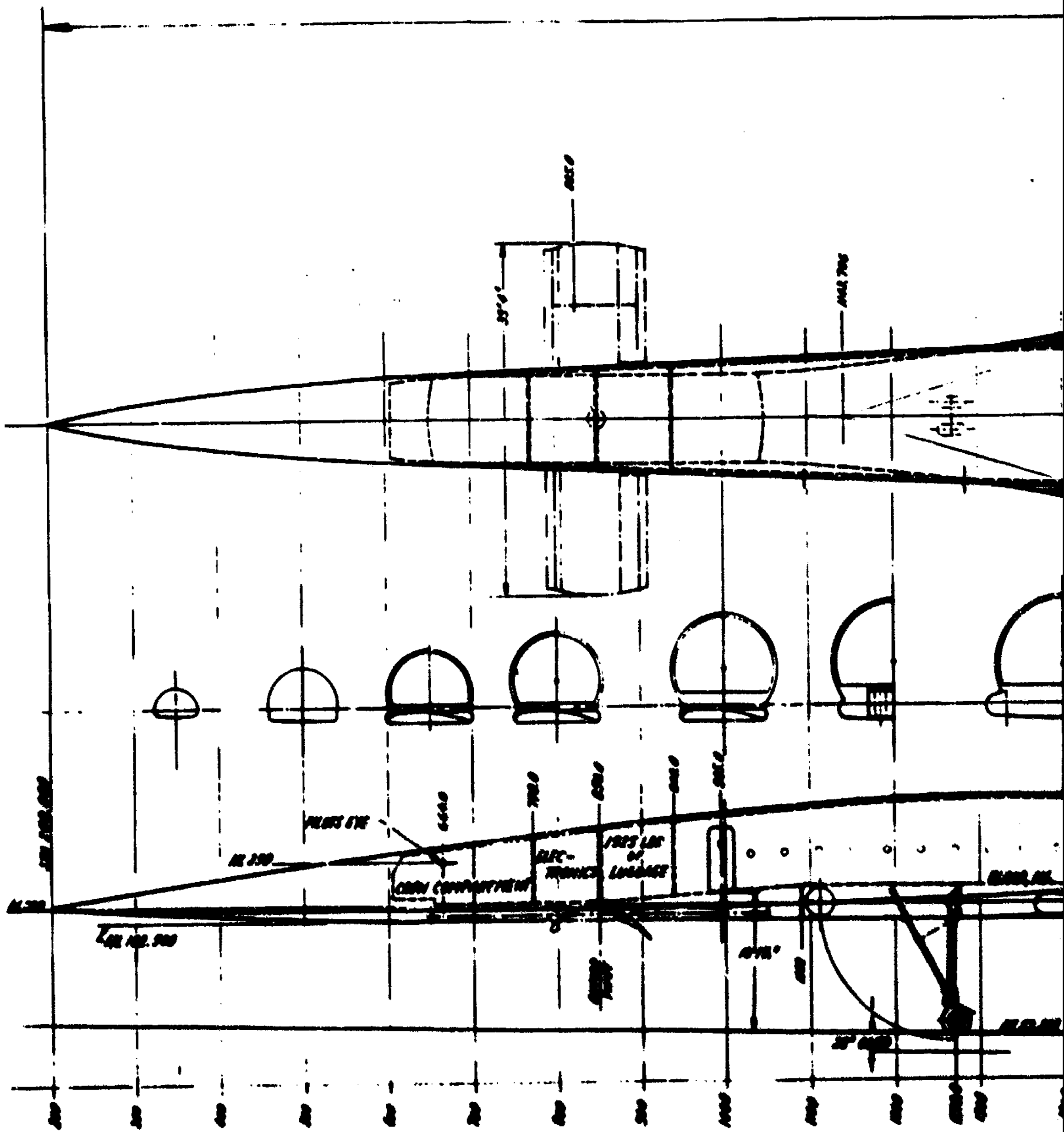

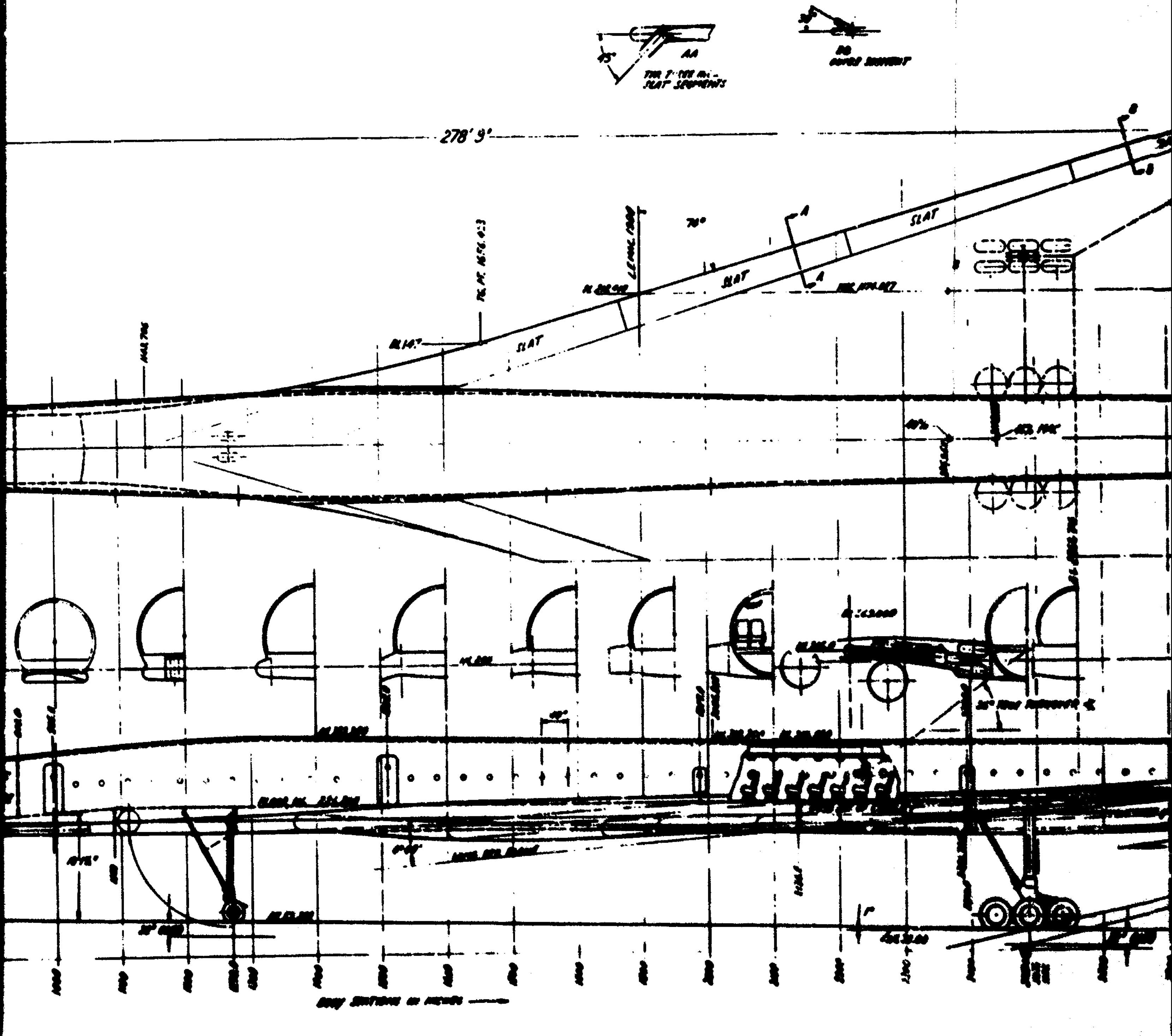

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Fig. 4-5 Modified

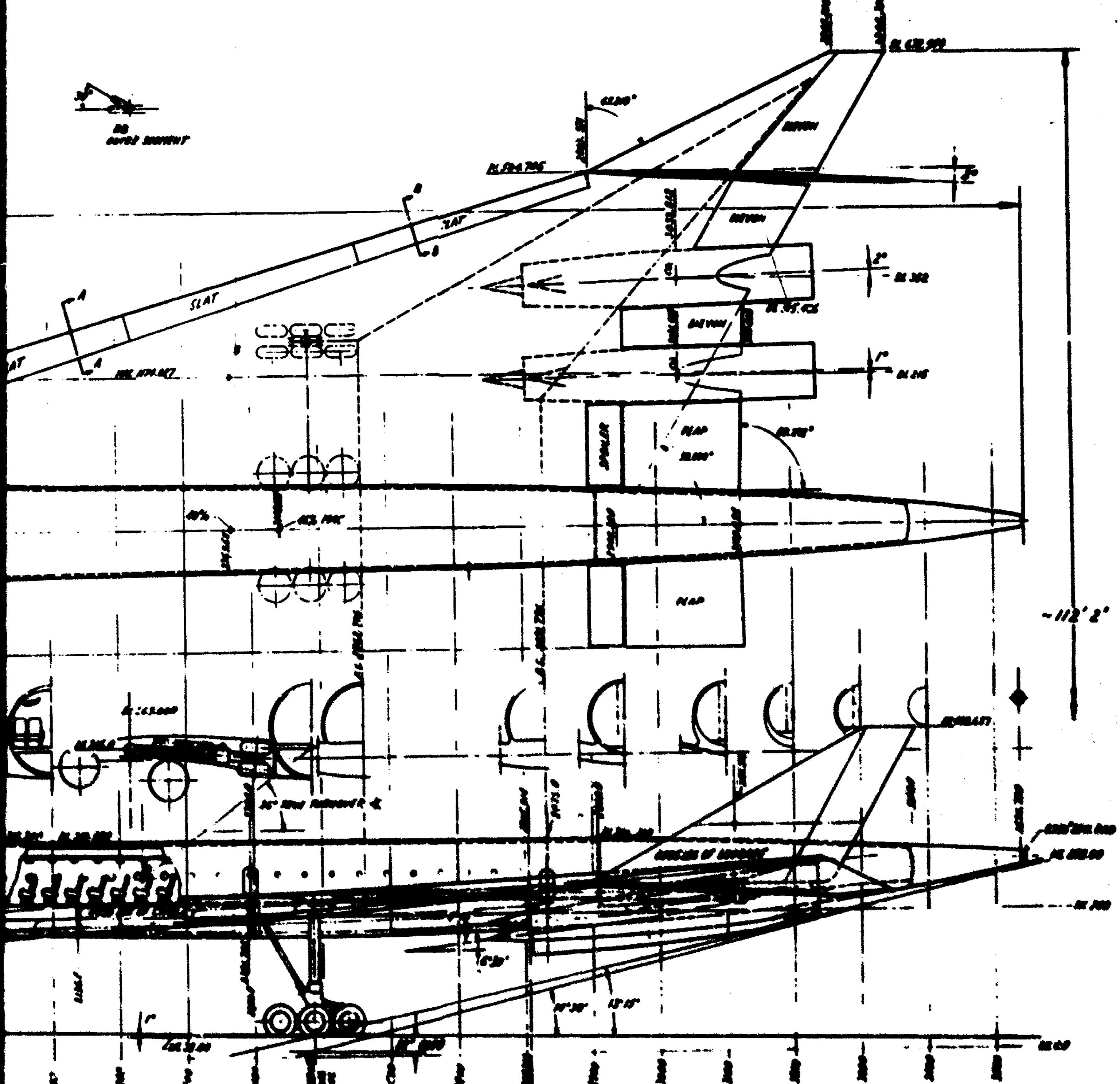

Fig. 4-5 Modified NASA 15F-220 - SCAT 15F-87

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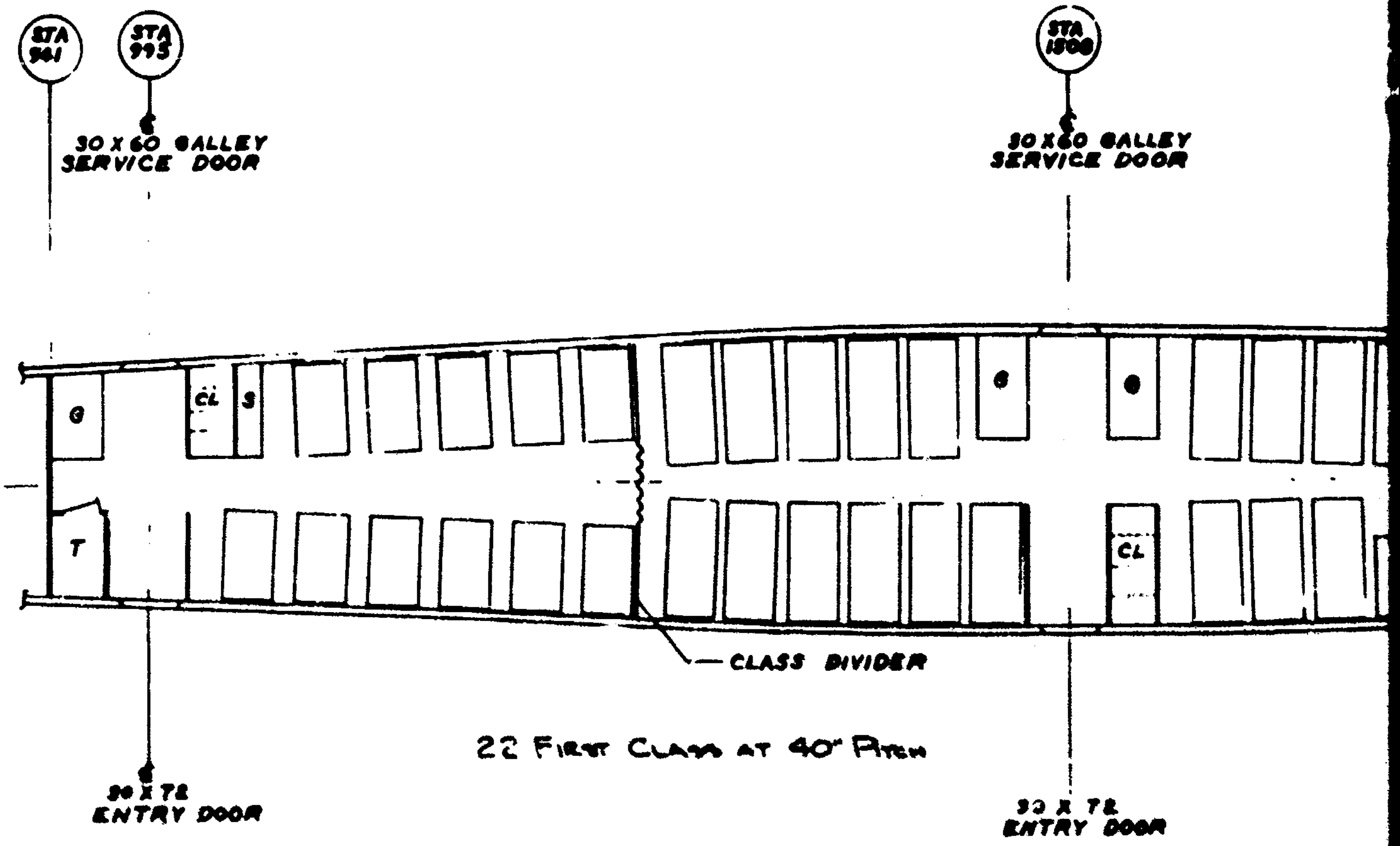
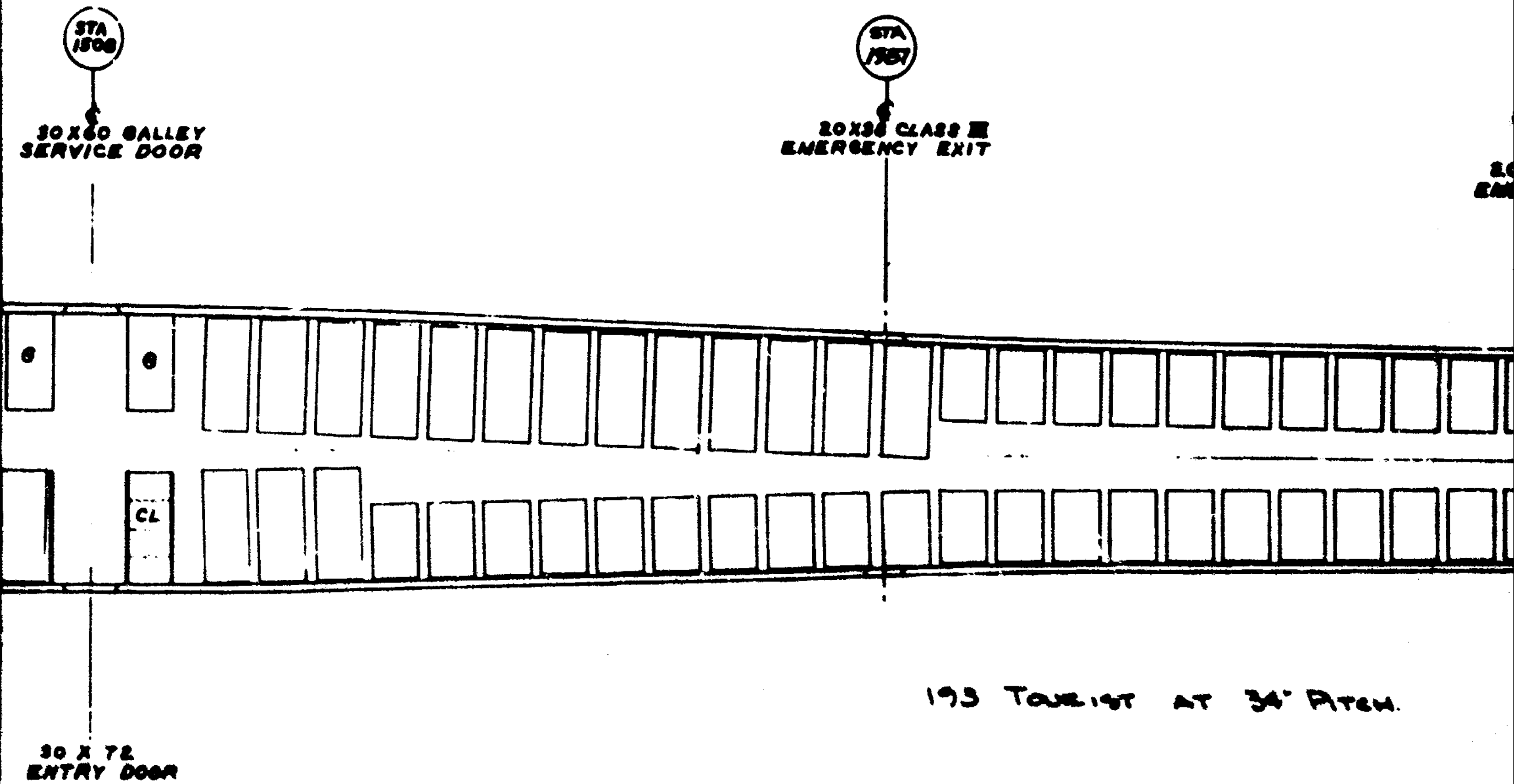
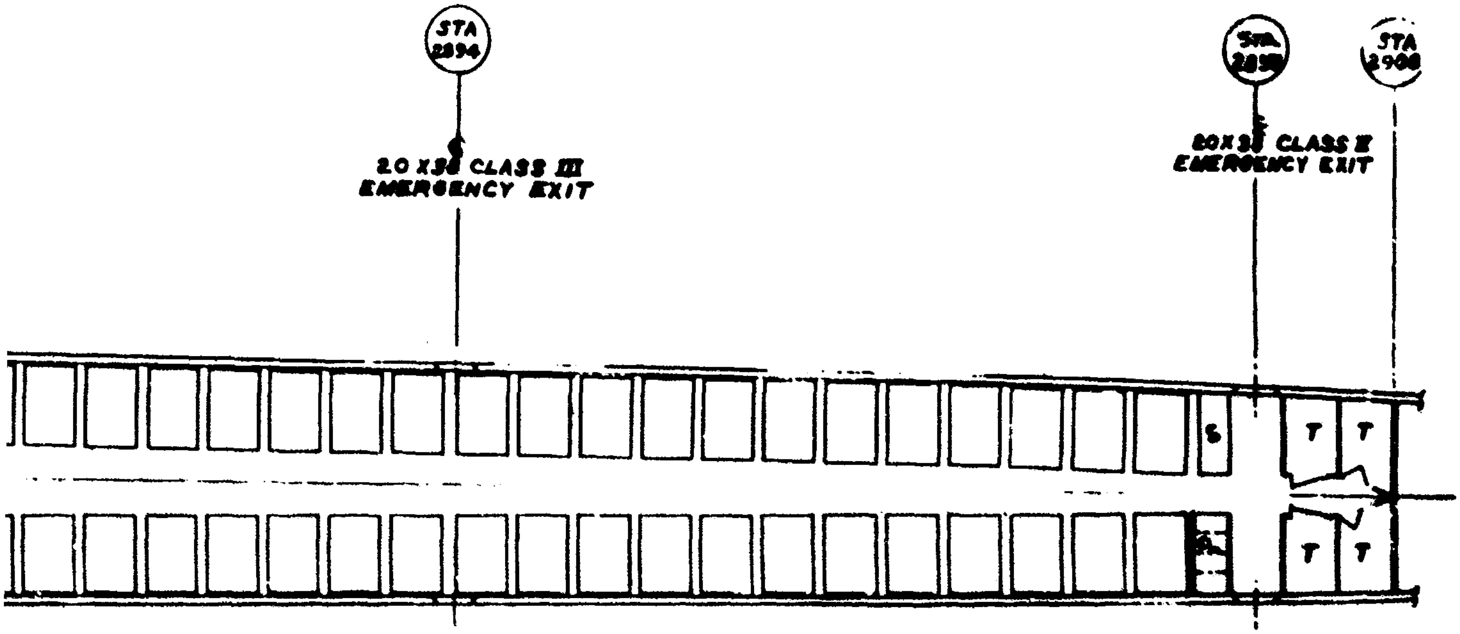

STA 941
STA 995
30 X 60 GALLEY SERVICE DOOR
STA 1508
30 X 60 GALLEY SERVICE DOOR
G
CL
S
T
G
G
CL
CLASS DIVIDER
22 First Class at 40" Pitch
30 X 72 ENTRY DOOR
33 X 72 ENTRY DOOR



215 PASSENGER ~ INTERNATIONAL MIXED CONFIGURATION

2



AT 34" PITCH.

<u>…ED CONFIGURATION</u>

Fig. 4-6 Interior Arrangement – Passengers

3

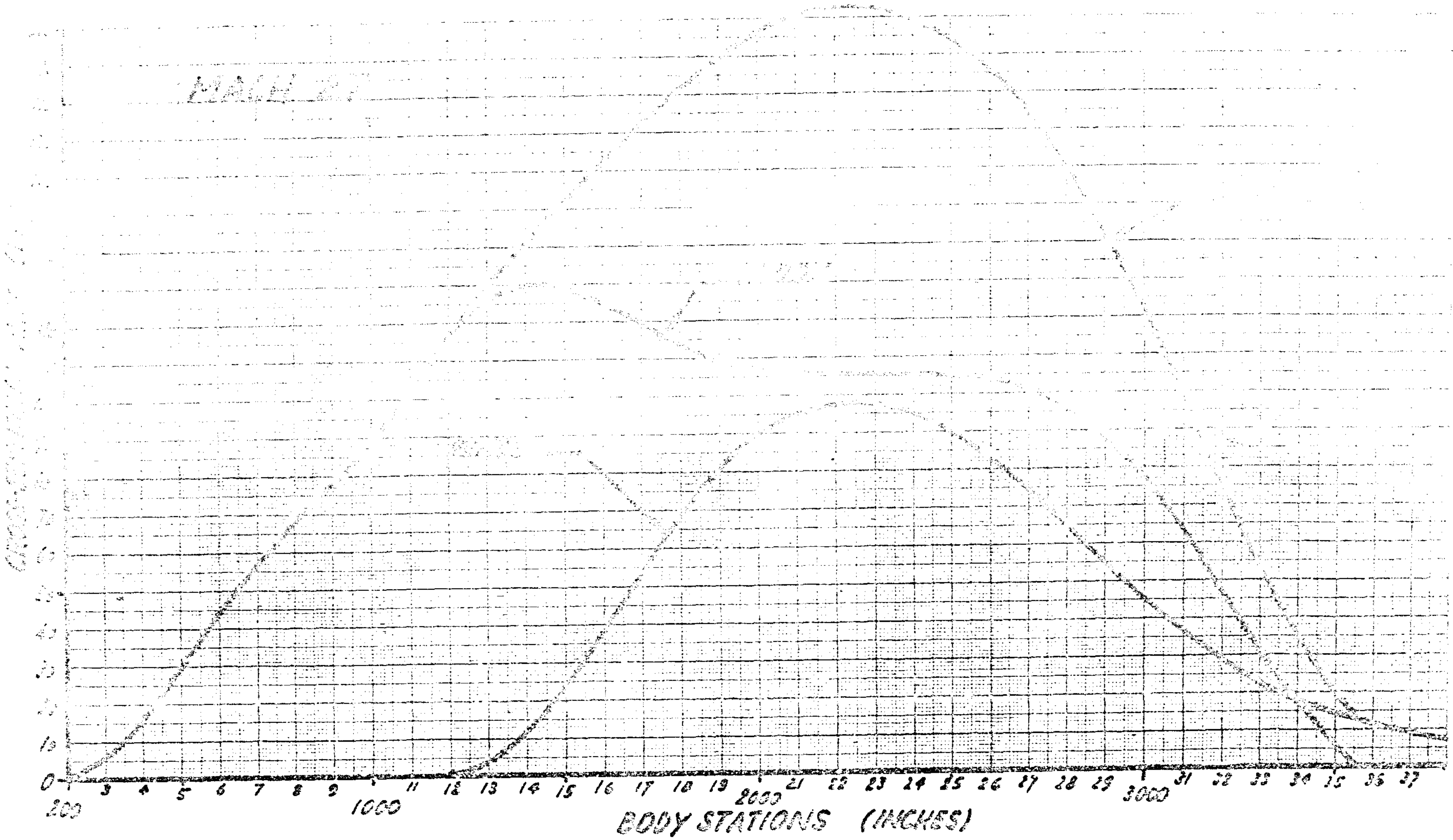


Fig. 4-7 M 2.7 Area Distribution

Table 4-C Wing Airfoil Data

y = SPAN

	.10y		.20y		.40y		.60y		.80y		1.0y	
% CHORD	Z_U	Z_L	Z_U	Z_L	Z_U	Z_L	Z_U	Z_L	Z_U	Z_L	Z_U	Z_L
0	4.481	4.481	2.935	2.935	1.151	1.151	0	0	0	0	0	0
2.5	4.559	4.306	3.073	2.831	1.409	1.141	0.274	0.007	0.184	- .087	.213	- .071
5	4.673	4.200	3.257	2.783	1.649	1.126	.536	.013	.358	- .164	.426	- .142
7.5	4.673	3.976	3.374	2.679	1.859	1.097	.757	- .004	.526	- .235	.568	- .142
10	4.663	3.757	3.410	2.508	2.030	1.040	.984	- .005	.679	- .292	.710	- .284
15	4.544	3.248	3.479	2.193	2.224	.822	1.347	- .055	.932	- .487	.923	- .497
20	4.352	2.710	3.443	1.816	2.378	.619	1.555	- .205	1.155	- .605	.995	- .710
25	4.102	2.158	3.361	1.441	2.430	.370	1.766	- .295	1.340	- .720	1.137	- .853
30	3.806	1.598	3.225	1.055	2.447	.140	1.895	- .415	1.493	- .816	1.208	-1.066
40	3.106	.504	2.815	.279	2.309	- .327	1.974	- .667	1.729	- .909	1.350	-1.279
50	2.307	- .521	2.268	- .454	1.990	- .758	1.877	- .871	1.857	- .890	1.350	-1.350
60	1.438	-1.443	1.598	-1.122	1.511	-1.129	1.650	- .991	1.899	- .739	1.208	-1.492
70	.476	-2.182	.791	-1.664	.885	-1.426	1.437	- .872	1.959	- .103	.853	-1.421
80	- .587	-2.691	- .143	-2.057	.323	-1.438	1.262	- .509	2.040	+ .280	.426	-1.279
90	-1.732	-2.949	-1.017	-2.113	- .182	-1.174	1.097	- .107	2.004	+1.013	- .071	-1.066
100	-2.714	-2.714	-1.861	-1.861	- .606	- .606	.941	+ .941	1.837	+1.837	- .710	- .710

Table 4-D Vertical Stabilizer & Rudder Data

At either wing B.L. 504.746, 75% span, one vertical stabilizer is located, inclined inboard 2° against free stream, extending above & below wing chord plane.

Each stabilizer has the following geometry:

Area ft^2	340 ft^2
Span	18'5"
Taper Ratio	.20
Aspect Ratio	1.0
Sweep at 25% Chord	57.6°
MAC	21'2"
Location of L.E. MAC Vertically from Root	7'2"
Tail Arm from 40% Wing MAC to 25% MAC Stabilizer	61'10"
Tail Volume Coefficient (Ref. Wing, Ref. MAC)	.047
Rudder:	
Area	113 ft^2
Span	18'5"
Chord	6'1"

Table 4-E High Lift Devices

INBOARD FLAP				
Distance from ℄ A/C to				
Inboard Edge (Ave.)	4'3"			
Outboard Edge	14'5"			
Max Deflection (Dwn)	13°			
Area (Total) Ft^2	300 ft^2			
Ground Clearance: To 13 1/4° ground line	0'			
LEADING EDGE SLATS	I	II	III	IV
Distance ℄ A/C to Inboard Edge	7'1"	15'6"	24'1"	32'7"
Distance ℄ A/C to Outboard Edge	15'5"	24'	32'6"	41'1"
Ave. Chord Length (Streamwise)	14'8"	12'2"	10'	7'4"
Area Total	280	210	170	130

Table 4-F Control Devices

SPOILERS			
Area Ft^2	80		
Chord Length	4'2"		
Chord % Loc. Wing Chord	3%		
Span	9'7"		
Spanwise Location			
Distance ℄ A/C to Inboard Edge	4'8"		
Outboard Edge	15'3"		
ELEVONS			
Area (Total)	142	150	217
Distance ℄ A/C to Inboard Edge	12'11"	33'	41'8"
Outboard Edge	21'3"	40'8"	56'1"
Chord Length	14'9"	10'	7'9"
Span	8'4"	7'8"	14'.5"
% Local Wing Chord	17.5%	23%	44%

Table 4-G Canard Data

Canard exposed only during subsonic flight.	
Area (Exposed)	200 ft^2
Chord Length	8'4"
Span	33'4"
Aspect Ratio	2.9
Taper Ratio	1.0
Thickness Ratio	14%
Distance .25$\bar{c}$ to .40$\bar{c}$ wing	128'9"
Volume Coefficient Based on Ref. Wing & Reference MAC	.033
L.E. Device	
Area	20 ft^2
T.E. Device	
Area	60 ft^2

Table 4-H Wetted Areas

	Ft^2
Fuselage	7900
Wing	12560
Vertical Stabilizer	1340
Nacelles	2452
	24252

5.0 ECONOMICS

The economics of the SCAT 15F-B7 airplane have been analyzed using the ground rules set forth in FAA Phase II-A. Direct operating costs are given for the airplane with the General Electric GE4/J5G and the Pratt & Whitney STF 219B engines.

Figure 5-1 shows the payload range and operating cost of the SCAT 15F airplane with both engines compared with the 707-320B Phase II-A Standard. At the design range, SCAT 15F-B7 has a direct operating cost of .92 cents per seat statute mile with GE4/J5G engines, or 1.04 cents per seat mile with P&W STF 219B engines. A comparison with the 707-320B standard at 4,000 statute miles shows DOC's 8 percent lower for SCAT 15F-B7 with GE4/J5G engines or 4 percent higher with P&W STF 219B engines. These airplanes have a community noise level similar to that of the 707-320B at the same range.

Variations in the design level of community noise as well as maximum range have an effect on the operating characteristics of an airplane. The estimated prices and DOC's resulting from a parametric analysis of SCAT 15F type airplanes are shown in Figs. 5-2, 5-3, and 5-4. The prices shown in Figs. 5-2 and 5-3 are based on 1964 dollars and exclude development cost. The total price of the SCAT 15F-B7 airplane with GE4/J5G engines is $22.2 million and with P&W STF 219B engines the price is $24.84 million. The airframe price for the 733-290 is shown in Fig. 5-2. The variation in airframe price for the SCAT 15F-B7 and the 733-290 is discussed in Section 8 Manufacturing Feasibility.

The direct operating costs of the SCAT 15F airplane are shown with the GE4/J5G engine and the P&W STF 219B (2200°F) engine in Fig. 5-4. The amortization of development costs has been included as a royalty in conformance with Phase II-A rules. The development cost of the SCAT 15F-B7 airplane with the GE4/J5G engine requires the amortization of 3.437 million dollars per airplane (300 airplanes), or $76.37 per block hour. With the P&W STF 219B engine the development cost is 5.203 million dollars per airplane or $115.63 per block hour.

For a constant design range, the airplane with the GE engine is quite sensitive to a change in design noise level (Fig. 5-4). A change in noise level from 112 PNdb to 105 PNdb at the design range of 4,000 statute miles results in an increase in DOC of 17 percent for the airplane with the GE engine, while a similar change in noise level produces an increase of 5 percent for the P&W engine configuration. For a constant noise level the two configurations show similar effects of change in design gross weight.

The effect of change in airframe price and the related change in DOC is shown in Fig. 5-5. The trade plot has been made for the base configuration, SCAT 15F-B7, with the GE4/J5G engine. The base airframe price is 17.8 million dollars. The graph shows that a change of 10 percent ($1.78 million) in airframe price results in a 2.2 percent increase in DOC.

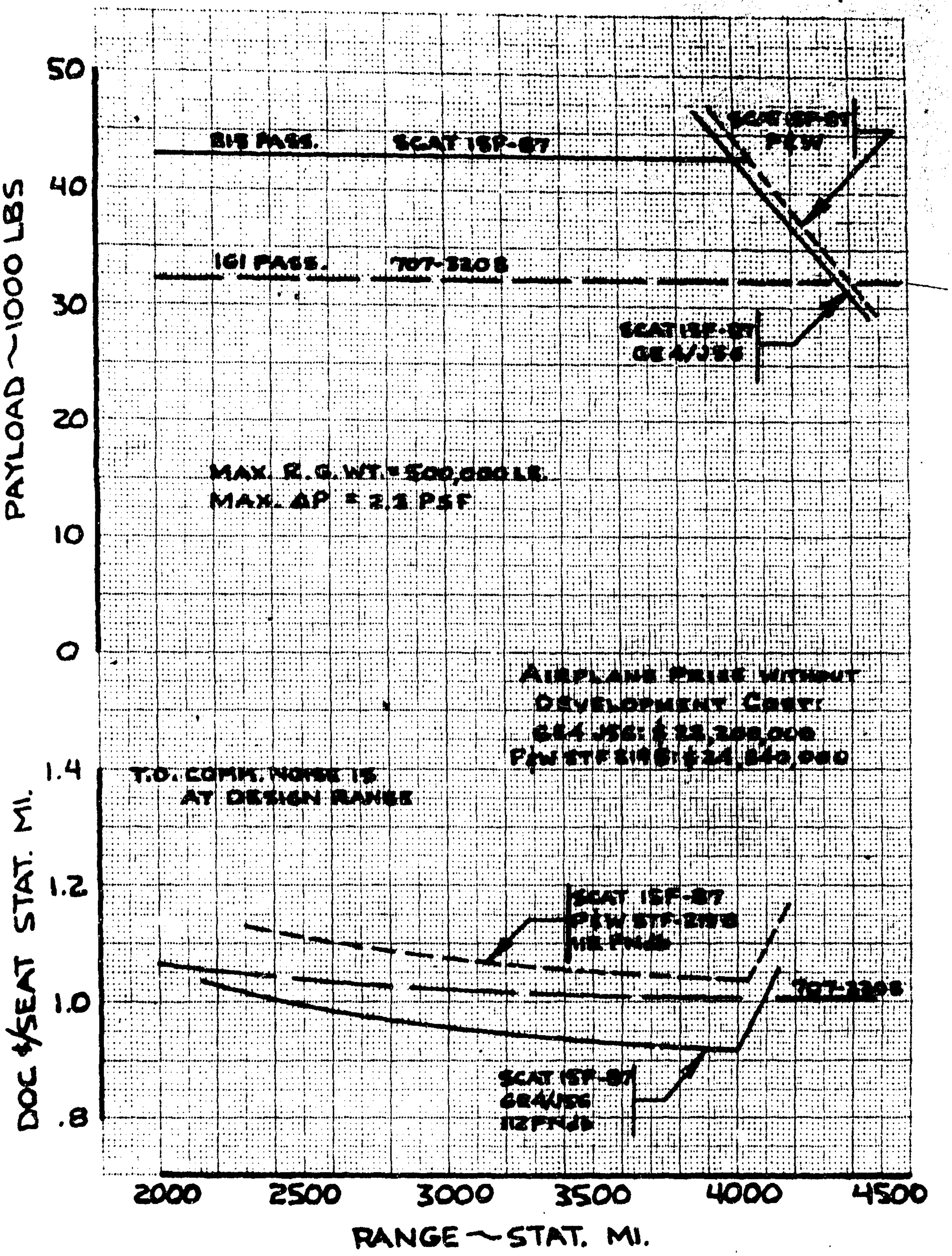


Fig. 5–1 Comparison of Payload-Range and DOC

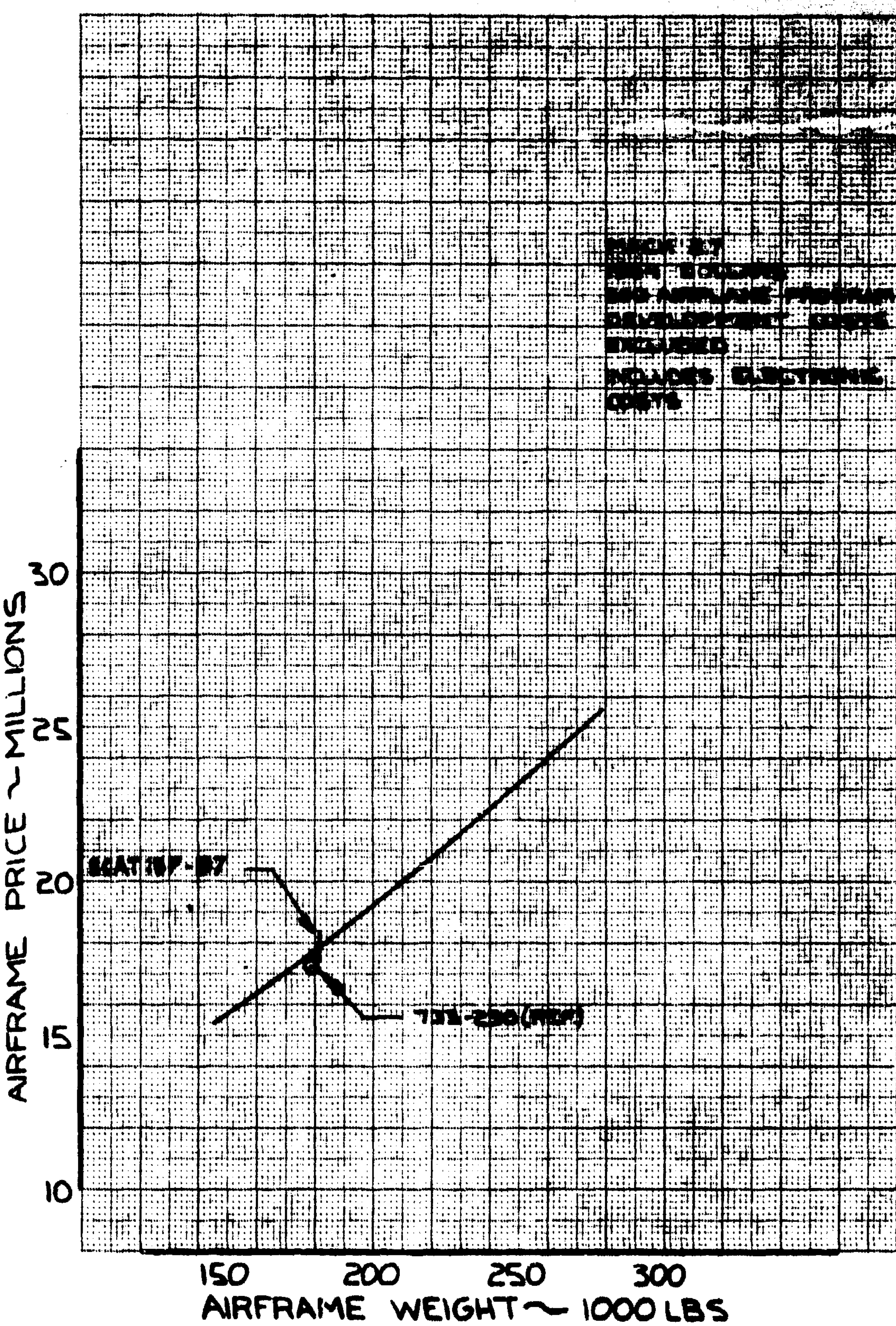


Fig. 5–2 Airframe Price Vs Weight
(SCAT 15F)

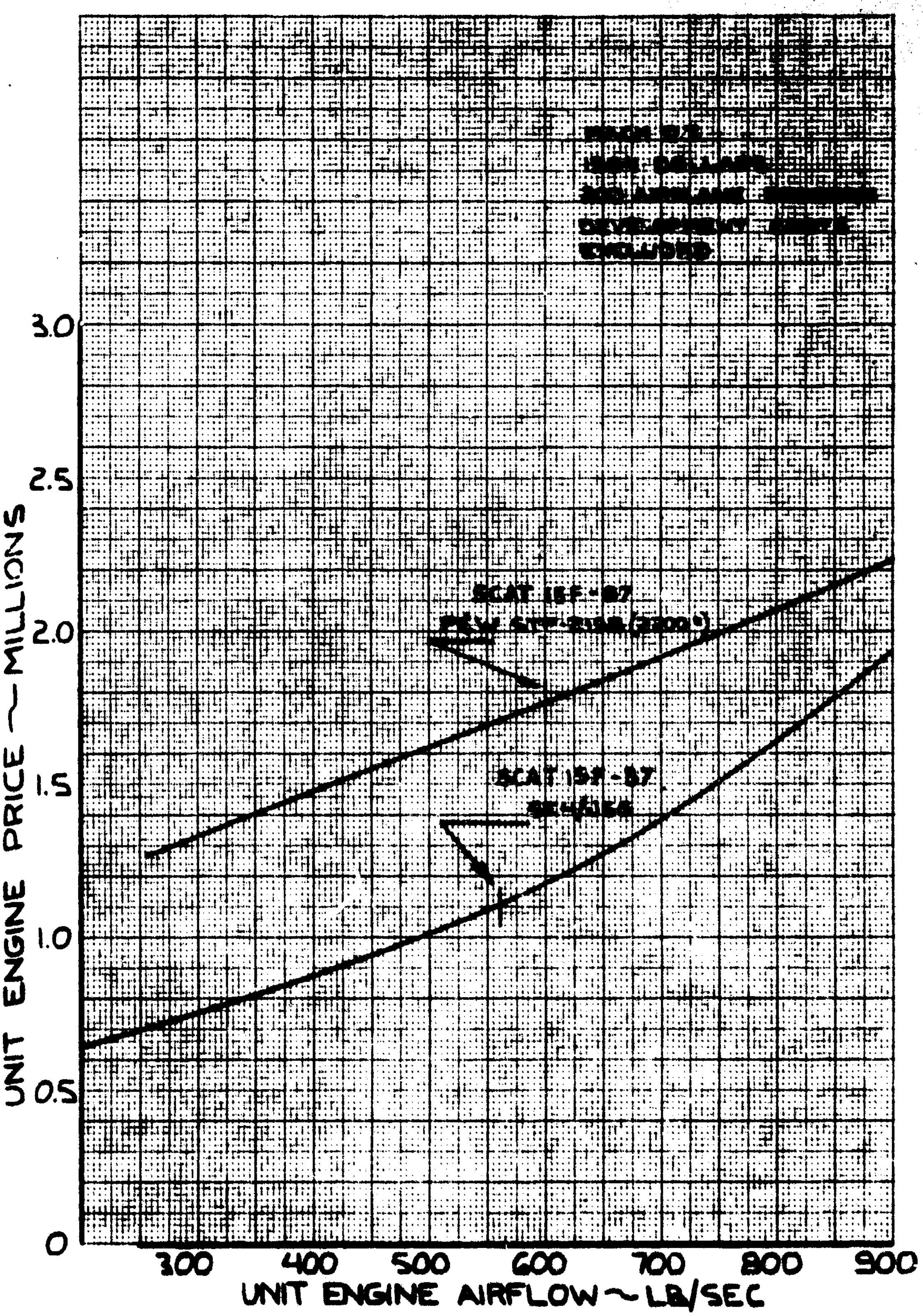


Fig. 5-3 Unit Engine Price Comparison

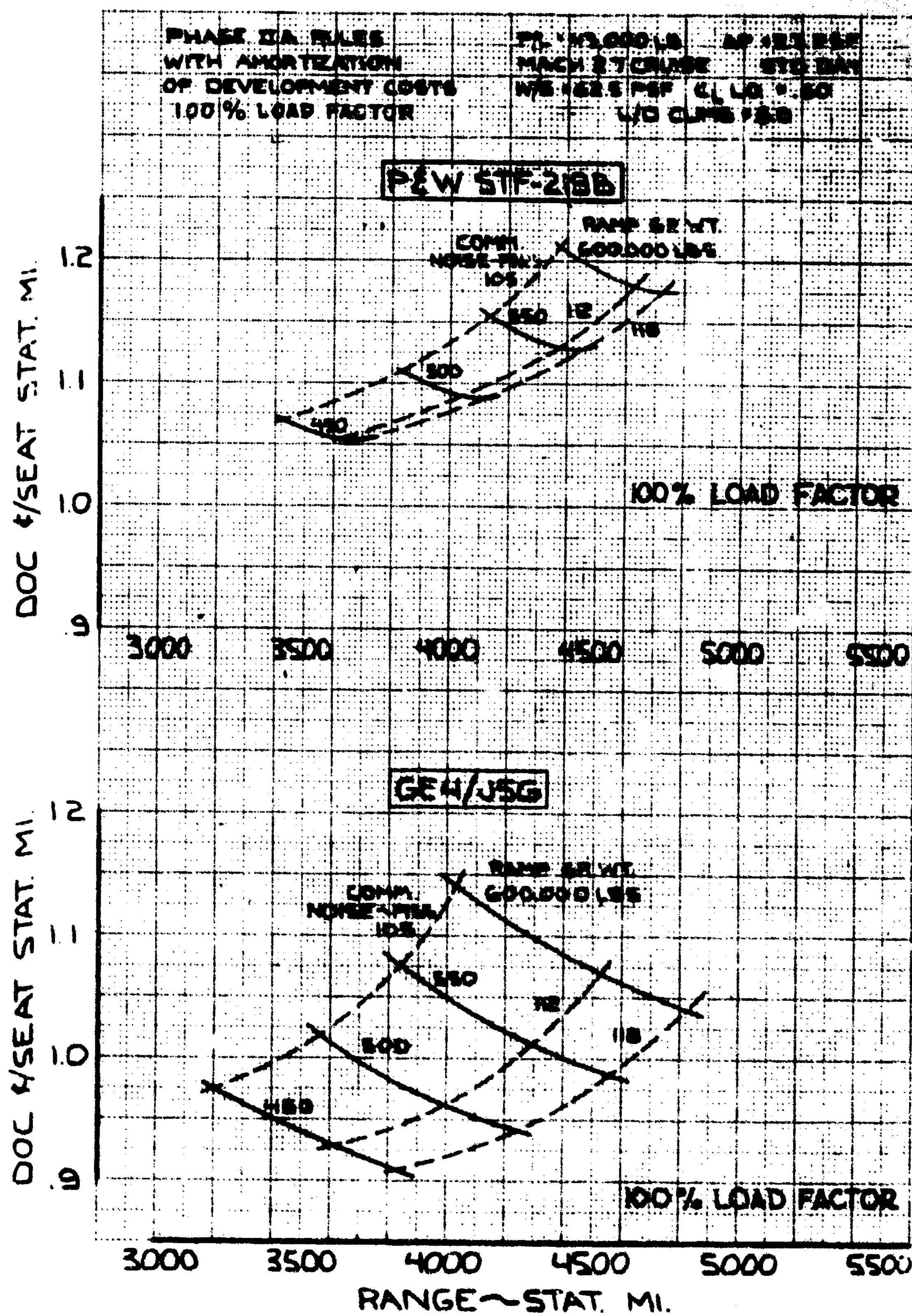


Fig. 5-4 DOC Comparison with G.E. and P&W Engines (SCAT 15F)

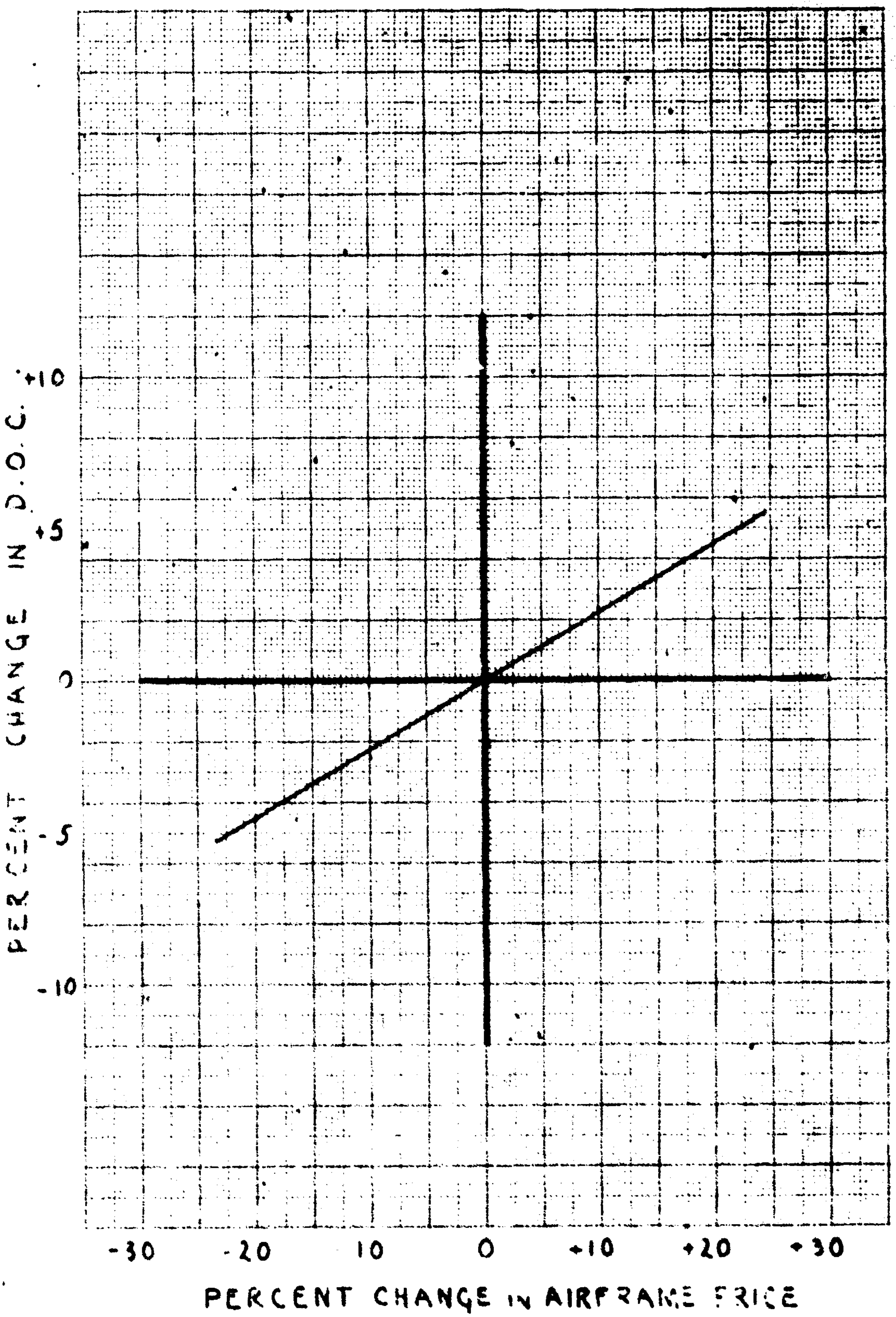


Fig. 5-5 Airframe Price Vs DOC (SCAT 15F)

6.0 WEIGHTS, BALANCE AND MOMENT OF INERTIA

6.1 WEIGHT VALIDATION

The airplane matching studies (Section 3.2.1) used the Operating Empty Weight, less propulsion pod and propulsion pod weight curves shown in Figs. 6-1 and 6-2.

The configuration selected as a result of the above studies, is shown in Fig. 4-5. The interior accommodations (Fig. 4-6) are for a basic mission payload of 215 mixed-class passengers and baggage at 200 pounds per passenger for a total of 43,000 pounds.

A summary of weights for this airplane is shown in Table 6-A. A Group Weight Statement with horizontal arms is provided in Table 6-B.

In general, the design philosophy, materials, construction, allowables, analysis methods, etc., used here are the same as those of the Boeing Model 733-290 (D6-8680-6, Book 2).

A weight substantiation of the Operating Empty Weight is provided in Sections 6.1.1 through 6.1.21.

Table 6-A Weight summary

	Lbs.
Manufacturer's Empty Weight	223,980
Standard Items	1,780
Basic Empty Weight	225,760
Operational Items	4,740
Operational Empty Weight	230,500
Number First Class Passengers	(22)
Number Tourist Passengers	(193)
Passenger and Baggage (200 lbs each)	43,000
Space Limited Payload (225 passengers)	52,200
Allowable Payload	59,100
Max Zero Fuel Weight	289,600
Max Design Landing Weight	340,000
Max Design Taxi Weight	500,000
Fuel Capacity at 6.7 lbs/gal	256,000
AMPR Weight	171,400
Airframe Weight (AMPR)(Economic)	181,000

6.1.1 Wing — 65,620 pounds

The wing structural arrangement is shown in Fig. 4-4. The materials, construction and allowables are basically the same as the Boeing Model 733-290.

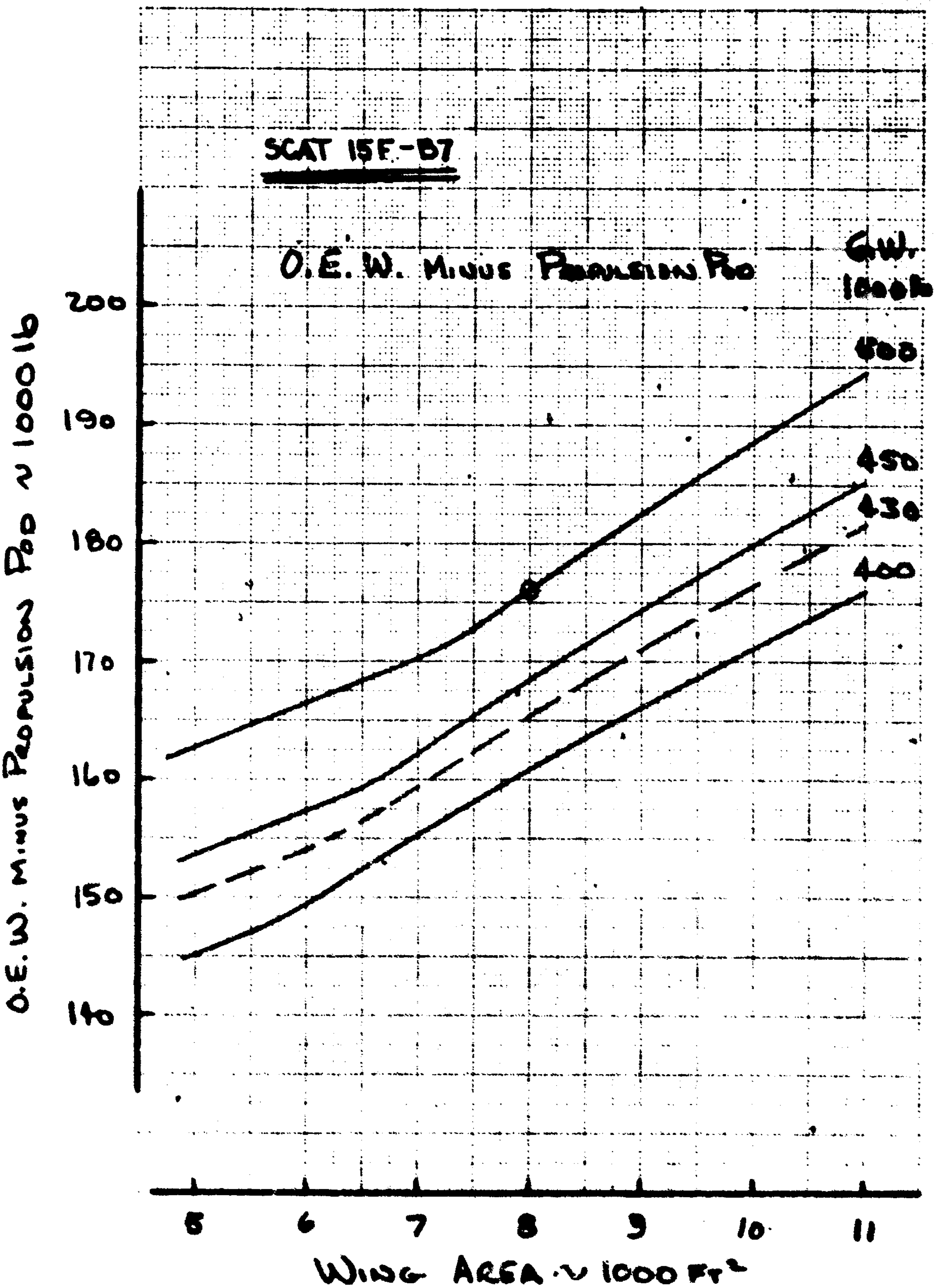


Fig. 6-1 O. E. W. - Propulsion Pod Weight

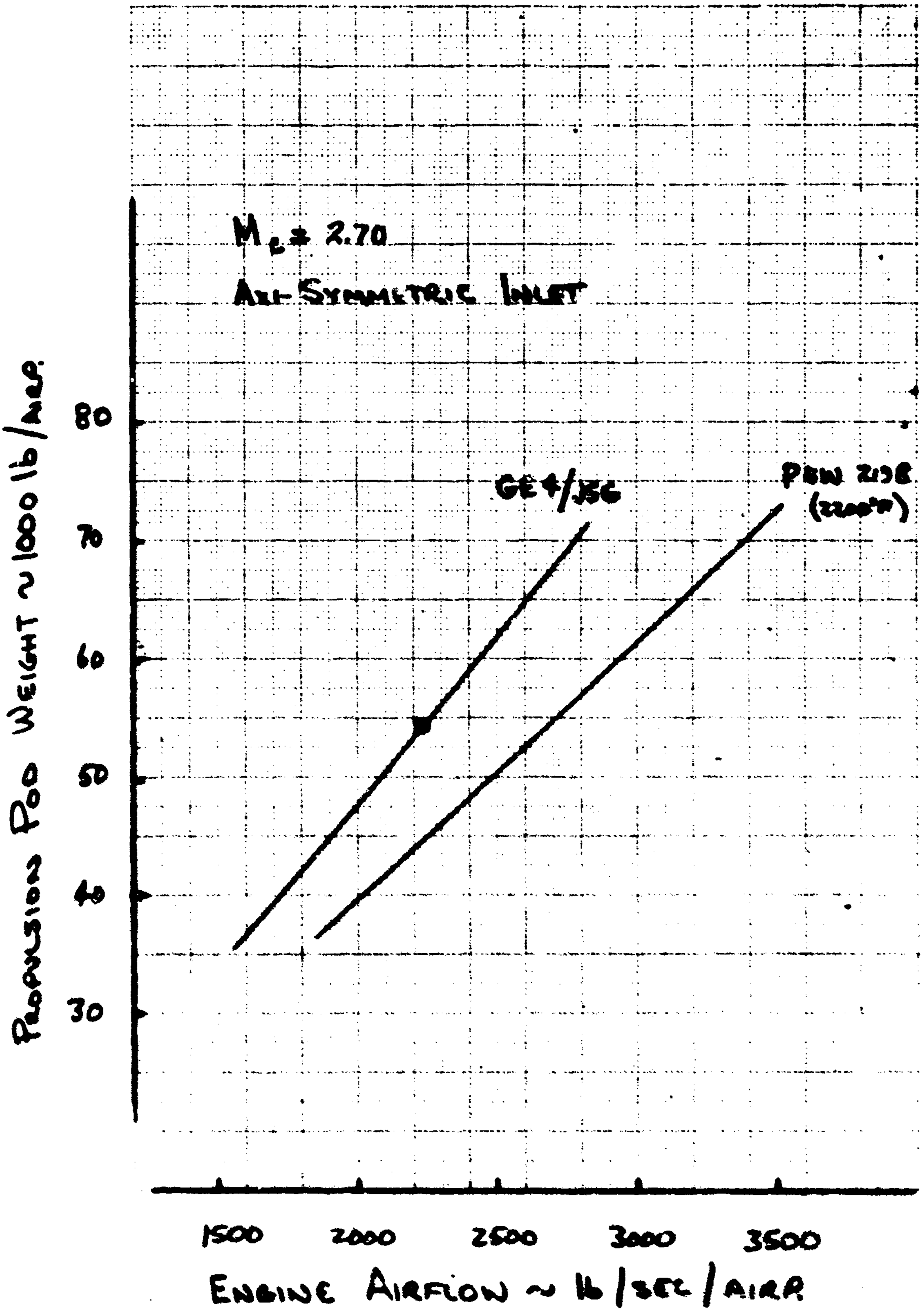


Fig. 6-2 Propulsion Pod Weight

Table 6-B Group Weights

	Weight	Arm
Wing Group	65,620	2,570
Canard	3,340	850
Vertical Tail	4,420	3,170
Body Group	32,720	1,850
Main Landing Gear	23,125	2,487
Nose Gear	2,020	1,150
Nacelle	9,220	2,865
Total Structure	(140,465)	(2,363)
Engine (Incl. T.R.)	43,920	3,090
Engine Accessories	650	2,825
Engine Controls	250	2,910
Starting System	350	2,768
Fuel System	3,750	2,490
Total Propulsion Group	(48,920)	(3,037)
Instruments	1,115	890
Surface Controls	5,770	2,530
Hydraulics	2,175	2,440
Electrical	4,705	1,665
Electronics	1,515	750
Furnishings	12,165	1,895
Air Conditioning	3,790	2,390
Anti-Icing	220	2,840
Insulation	3,135	1,965
Total Fixed Equipment	(34,595)	(1,988)
Manufacturer's Empty Weight	223,980	2,452
Unusable Fuel	470	2,414
Unusable Oil	250	3,030
Emergency Equipment	325	1,795
Unusable Water - Wash & Drink	10	1,314
Toilet Water & Chemical	125	2,484
Galley Structure	600	1,314
Total Standard Items	(1,780)	(2,015)
Basic Empty Weight	225,760	2,448
Crew and Crew Baggage	1,385	1,410
Usable Oil	60	3,030
Emergency Equipment	1,436	1,770
Usable Water - Wash & Drink	367	1,314
Passenger Service Equipment	559	1,916
Food & Beverage	264	1,314
Galley Service	669	1,314
Total Operational Items	(4,740)	(1,573)
Operational Empty Weight	230,500	2,431

The weight analysis used is as described for the 733-290 with the following modifications:

- Interspar splices and joints and rib weight factors have been increased to reflect the lower end load level of this wing.
- Control surface and secondary structure unit weights used are based on the 733-290 values.

The ultimate wing shears, moments and torsions are shown in Section 7. The average theoretical bending material is shown in Fig. 6-3.

6.1.1.1 Design Data

Area	Ref.	8000
	Gross	8396
Leading Edge Sweep	74°,	65°
Aspect Ratio	1.57	
Taper Ratio	.040	
Thickness Ratio	2.75 Average	

6.1.1.2 Weight Substantiation
Table 6-C lists wing weight details.

Table 6-C Detail Wing Weight

Bending Material (See Fig. 6-3)		15,250
Shear Material		2,290
Splices and Joints	45% B.M.	6,865
Interspar Ribs	45% B.M.	6,865
Center Section		1,610
Forward Strake	At 5.50 PSF	13,090
Forward Strake - Slats	At 5.65 PSF	4,405
Outboard Leading Edge	At 3.67 PSF	1,250
Vertical Tail Supt. and Penalty		1,000
Trailing Edge	4.25 inbd, 2.63 outbd.	2,820
T.E. Flaps	At 6.0 PSF	1,750
Elevons	At 6.0 PSF	2,535
Spoilers	At 3.0 PSF	220
Engine Support Structure Penalty		1,400
Landing Gear Doors	At 4.3 PSF	1,250
Access Doors	(-290)	560
Tip	At 4.0 PSF	550
Miscellaneous		1,910
TOTAL		65,620 lbs

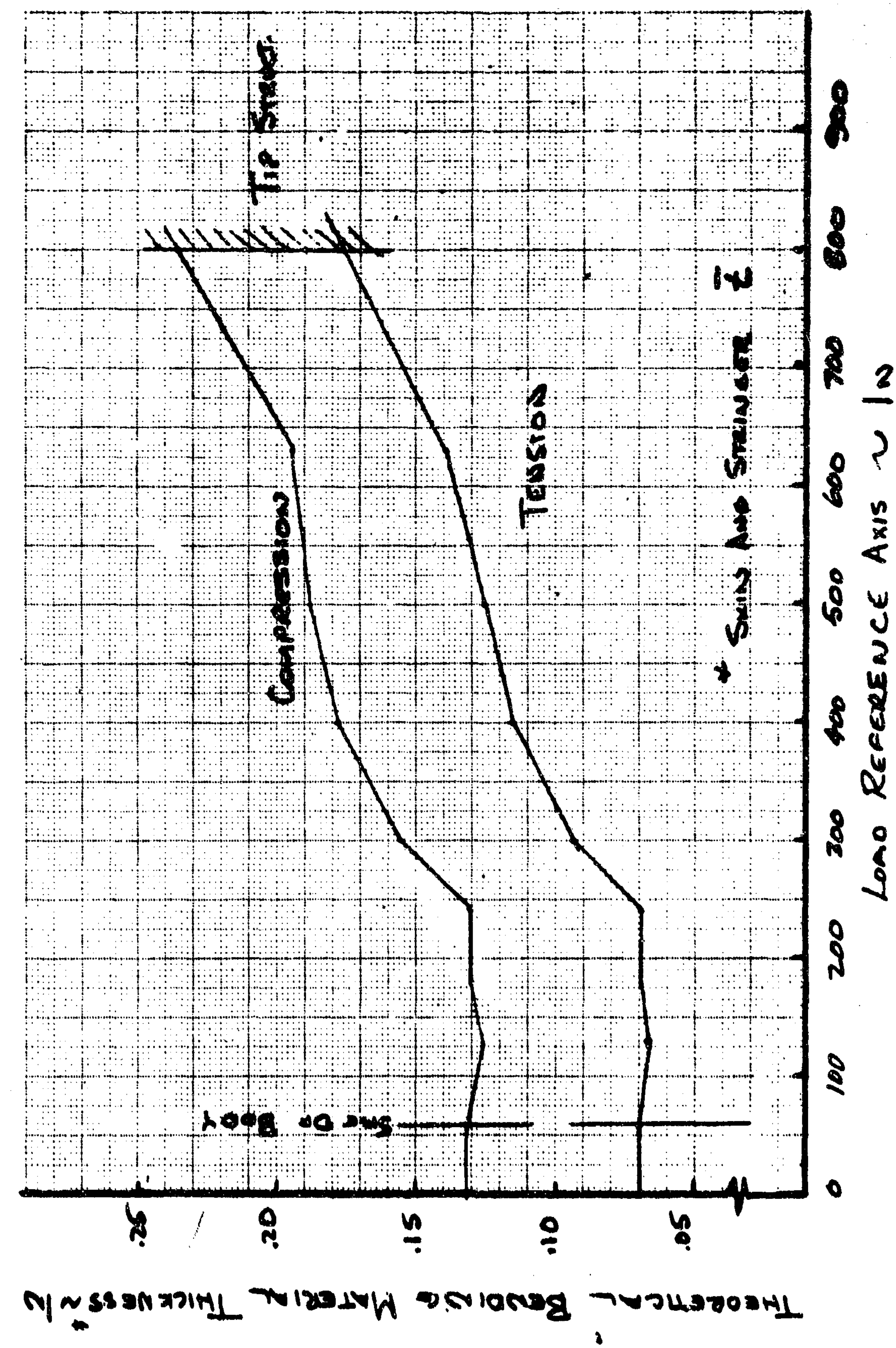


Fig. 6-3 Average Theoretical Bending Material

6.1.2 Canard 3,340 pounds

The canard is a retractable surface with leading and trailing edge high lift devices.

Construction materials and allowables are similar to the 733-290 wing. The Unit Weight used is based on empirical data with an allowance for a pivot and movable fairings.

6.1.2.1 Design Data

Area (Exposed)	200 sq ft
(Gross)	278 sq ft
Leading Edge Sweep	0 degrees
Aspect Ratio (Exposed)	2.5
Taper Ratio	1.0
Thickness Ratio	14%

6.1.2.2 Weight Substantiation

Basic Surface 278 sq ft (9.0 PSF)	= 2500 lbs
Pivot Penalty (Canard)	= 270
Pivot Structure (Body)	= 330
Body Fairing Doors and Actuation	= 240

6.1.3 Vertical Tail 4,420 pounds

The vertical tail consists of two fixed fins, with single segment rudders, mounted on the outboard wing.

Construction, materials, and allowables are similar to those on the 733-290 vertical tail.

The Unit Weight used is based on the 733-290 values considering the changes in geometry and loading.

Due to the fact that local wing structure is designed by fin loads, the attachment penalty is carried in wing structure weight.

6.1.3.1 Design Data

Area	340 sq ft each
Leading Edge Sweep	62 degrees
Aspect Ratio	1.0
Taper Ratio	.2
Thickness Ratio	3.0%

6.1.3.2 Weight Substantiation

340 sq ft (6.5 PSF) = 4420 lbs

6.1.4 Body 32,720 pounds

Construction, materials and allowables used are the same as on the 733-290. The analysis method, unit weights, etc., used are the same as described in D6-8680-6 (733-290).

The relative weight saving resulting from the absence of fuel and empennage is partially offset by the canard and longer body.

6.1.4.1 Design Data

Body loads are shown in Section 7. Effective depth is shown in Fig. 6-4.

6.1.4.2 Weight Substantiation

Table 6-D lists body weight details.

The monocoque material distribution is shown in Fig. 6-5.

Due to the additive canard load, the positive bending on dynamic landing may become critical for a portion of the forebody. Time did not allow a complete analysis of this condition therefore an estimated penalty of 800 pounds has been included in the structure.

Table 6-D Detail Body Weight

Monocoque (Skin and Stringers) (See Fig. 6-5)			13,820 lbs
Frames (Including Tear-Stoppers) 22% (Monocoque)			3,040
Bulkheads (-290) - Fuel			2,380
Floors and Floor Supports	At 3.70 and 1.45 PSF		4,010
Doors, Hatches, and Operating Mechanisms		-290	2,960
Windows and Window Frames			410
Canopy			1,690
Windshield			880
Nose Wheel Well Cutout Penalty		-290	500
Tail Cone	At 1.7 PSF		200
Keel Chord			880
Wing-Body Fairing (Incl. Canard)			320
Stabilizer Cutout Penalty		-290	240
Wing-Body Attachment Fittings			240
Production Joints			90
Seam Seal and Finish		-290	180
Miscellaneous			880
TOTAL WEIGHT			32,720 lbs

6.1.5 Main Landing Gear 23,125 pounds

The main gear is wing mounted, retracting inboard into the wing. Each truck has six wheels and tires. The gear has crosswind landing features.

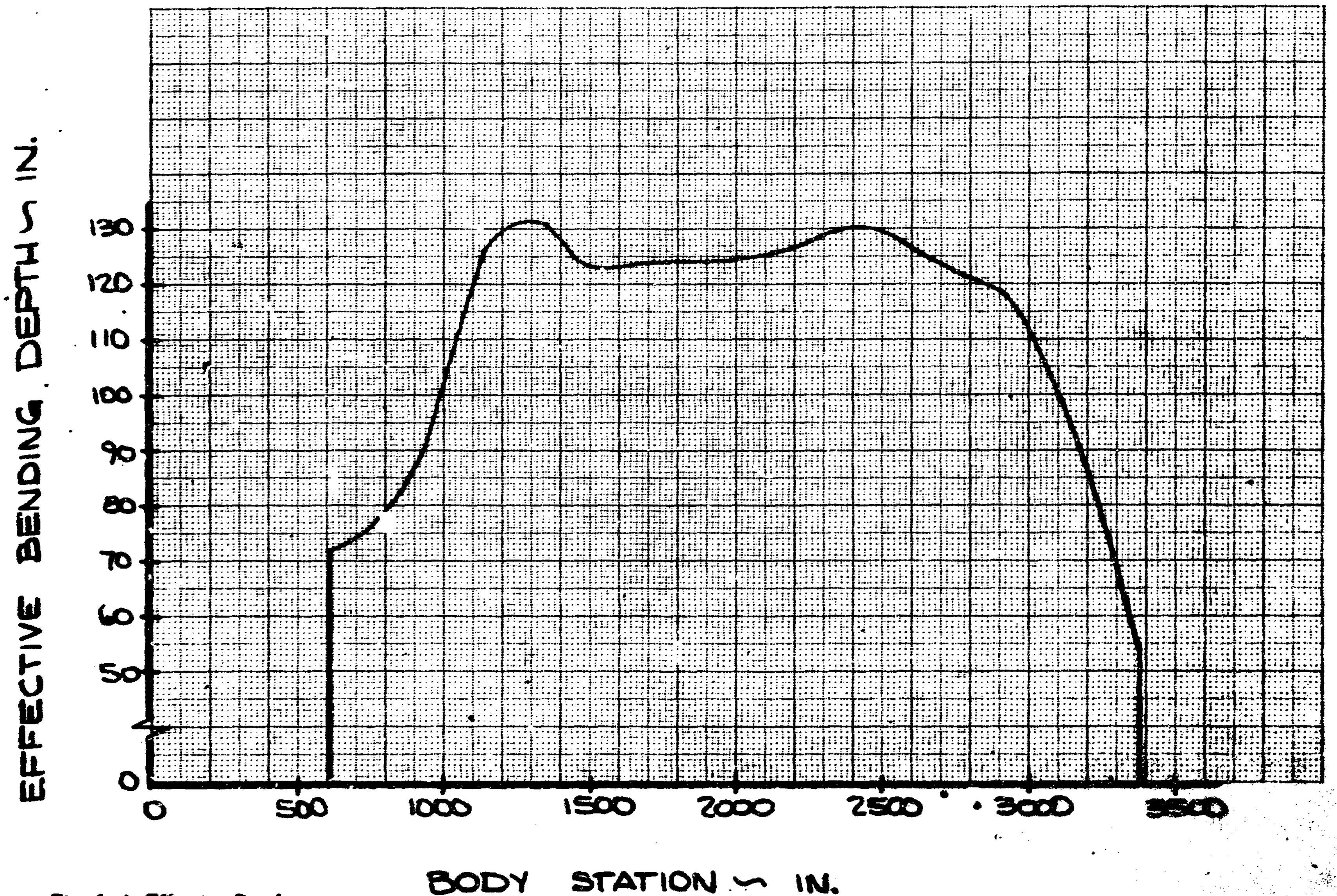


Fig. 6-4 Effective Depth

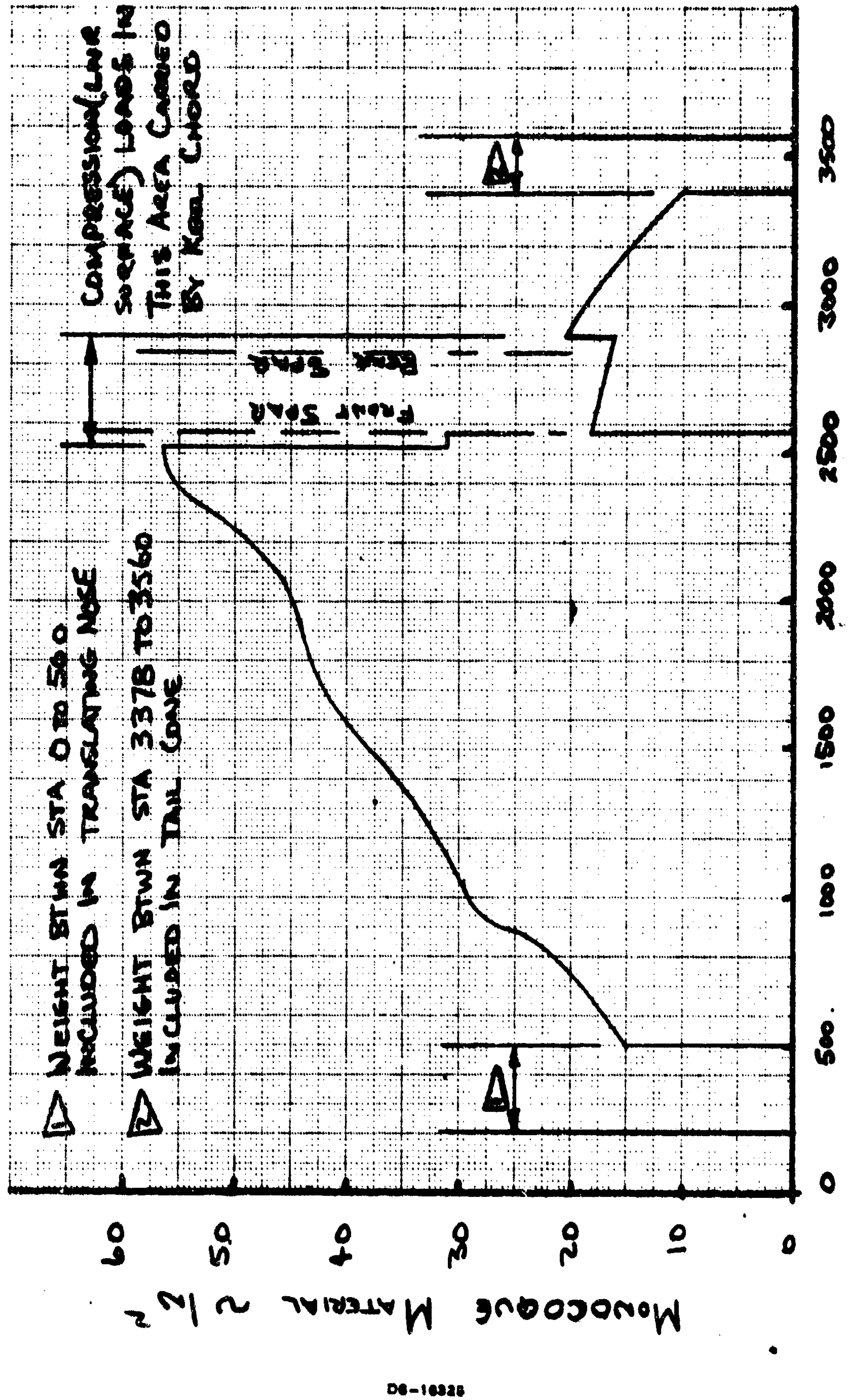


Fig. 6-5 Monocoque Material Distribution

6.1.5.1 Design Data

Maximum Design Taxi Weight	500,000 lbs
Maximum Design Landing Weight	340,000 lbs
Length (Trunnion to Static Ground Line)	184 in.
Tires (12) 46 X 16 Type VII	

6.1.5.2 Weight Substantiation

733-290 (four wheel truck 129 in. long)		17,050
Length Increase (184-129)		
	$\frac{2400}{30}$ (55)	= + 4,400
Six Wheel Truck		= + 1,400
Tires 46 X 16-inch (40 X 14)		
	12 (170)-1920	= + 120
Wheels		
	12 (150)-1720	= + 80
Brakes		
	2130-2520	= - 390
Air		
	105-90	= + 15
Crosswind Feature		= + 450

6.1.6 Nose Gear 2,020 pounds

The nose gear is similar to the 733-290 with the exception of a length increase of 46 inches.

6.1.6.1 Weight Substantiation

Length Increase (147-100-in.)

$$865 + \frac{147}{100} (785) = 2020$$

6.1.7 Nacelle 9,220 pounds

Inlets	(4)	(2000)	= 8000 lb
Engine Cowl	(4)	(305)	= 1220 lb

The inlet and cowl design, construction, materials and allowables are the same as the 733-290.

The weights have been scaled from the 733-290 to reflect the increased engine airflow requirements.

6.1.7.1 Design Data

Engine	GE4/J5G
Airflow (Sea Level Static)	560 lb/sec
Mach No. - Cruise	2.7
Inlet Face	2.55

6.1.7.2 Weight Substantiation

Inlet $1670 \left(\frac{560}{475}\right) 1.1$ = 2000 lb

Engine Cowl $250 \left(\frac{560}{475}\right) 1.2$ = 305 lb

6.1.8 Engine (Boeing Installed) 4 (10980) 43,920 pounds

The engine is a GE4/J5G augmented turbojet. The weight is scaled from the 733-290 to reflect the increased airflow requirement.

6.1.8.1 Design Data

Cruise Mach Number	2.7
Sea Level Static Airflow	560 lb/sec
Fully expanded convergent - Divergent nozzle	

6.1.8.2 Weight Substantiation

$$9015 \left(\frac{560}{475}\right)^{1.2} = 10,980 \text{ lbs}$$

6.1.9 Engine Accessories = 650 lbs

6.1.10 Engine Controls = 250 lbs

6.1.11 Starting System = 350 lbs

The above systems are assumed the same as the 733-290 values.

6.1.12 Fuel System 3,750 pounds

The fuel system design, materials, etc., are the same as the 733-290 with the elimination of body fuel cells.

6.1.12.1 Design Data

System Capacity 38,210 U. S. Gal.
256,000 lb at 6.7 lb/gal

6.1.12.2 Weight Substantiation

733-290 Fuel System	5,100 lbs
Delete	
Body fuel cells	-1,161
Miscellaneous Plumbing and Vents	- 189

6.1.13 Surface Controls 5,770 pounds

The system is based on the same design philosophy as the 733-290.

The weights have been adjusted to account for surface functions, changes and deletions.

6.1.13.1 Weight Substantiation

733-290 System Weight	8,370 lb.
Delete	
Sweep Actuation System	- 2,708
Horizontal Stabilizer System	- 924
Horizontal Stabilizer Flap System	- 381
Outboard Spoilers	- 263
Inboard and Outboard Flaps	- 652
Aileron System	- 824
Add	
Second Fin Penalty	+ 320
Elevon System	+ 2,470
Canard System	+ 360

The following systems are assumed the same as the 733-290 considering the increased cabin and run lengths.

	System	733-290 Weight Pounds	Δ Weight for Length (pounds)	Total Weight (pounds)
6.1.14	Hydraulics	2,100	+ 75	2,175
6.1.15	Electrical	4,440	+ 265	4,705
6.1.16	Furnishings	11,620	+ 545	12,165
6.1.17	Air Conditioning	3,720	+ 70	3,790
6.1.18	Insulation	2,880	+ 255	3,135

6.1.19 Electronics 1,515 pounds

The electronics weights reflect a wire weight saving by moving the compartments to the upper lobe locations.

6.1.19.1 Weight Substantiation

733-290 System Weight	1,810
Additional Run Length	+ 25
Move to Upper Deck	- 320

6.1.20 Unusable Fuel 470 pounds

The reduction of the body fuel cells and the associated plumbing allows a reduction in unusable fuel.

Weight Substantiation

733-290 Weight	550
Delete Body Cells	- 80

6.1.21 Remaining Weights

All remaining weights are assumed to be the same as the 733-290.

6.2 Balance

The balance and loading characteristics of this airplane meet the following objectives:

- It is a completely loadable airplane with no ballast requirements.
- No seating restrictions are necessary.
- One standard, simple, fuel loading and management procedure is used for all missions. It does not require computer or manual switching to achieve minimum of travel of the airplane center of gravity as fuel is consumed.
- Flexibility in loading is provided with forward, mid, and aft locations of cargo compartments.

6.2.1 Airplane Balance Data

The Basic Mission balance diagram is shown in Fig. 6-6.

6.2.2 Fuel Management

The fuel system consists of four main fuel tanks which are loaded and used equally.

6.3 Moment of Inertia

The basic mission inertia diagram is shown in Fig. 6-7.

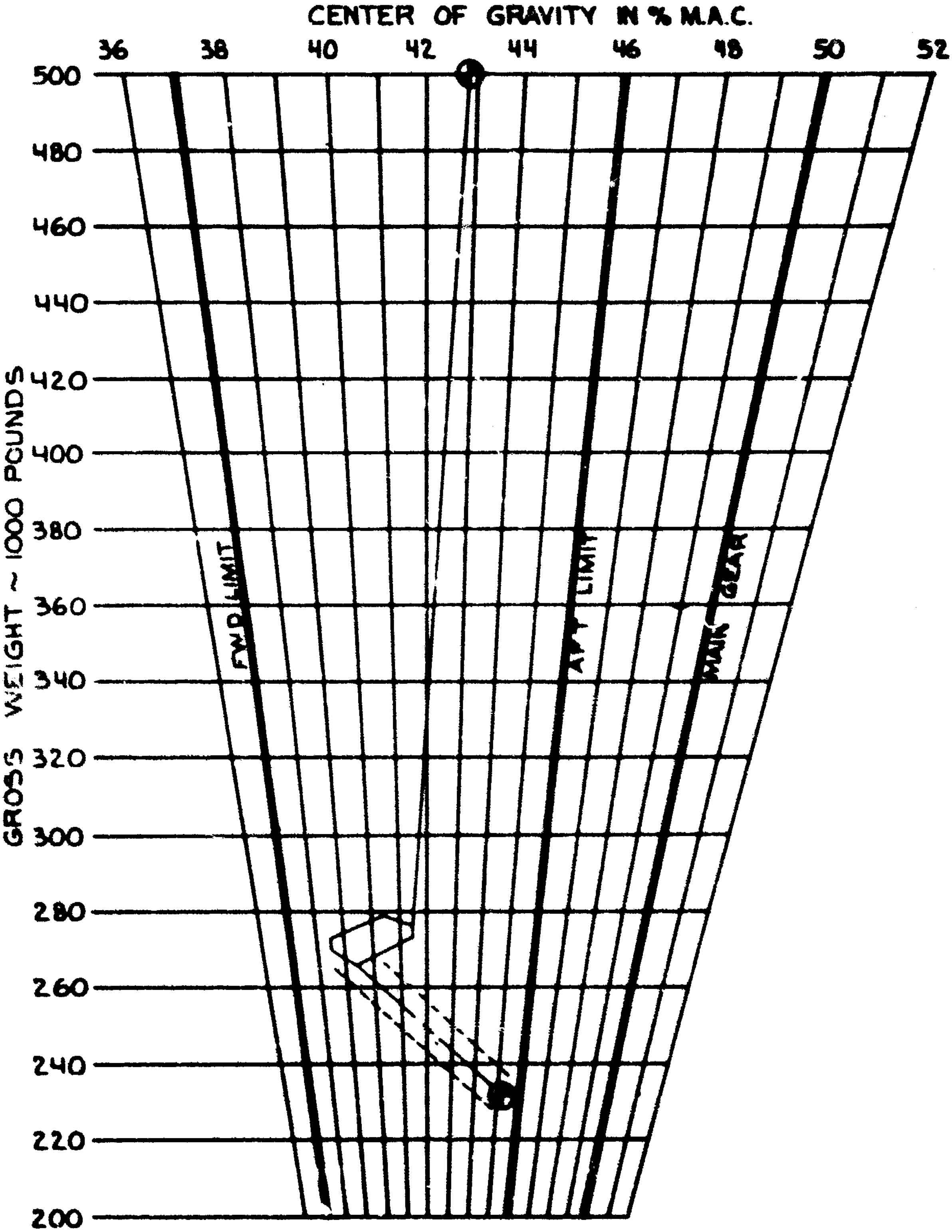


Fig. 6-6 Basic Mission Balance Diagram.

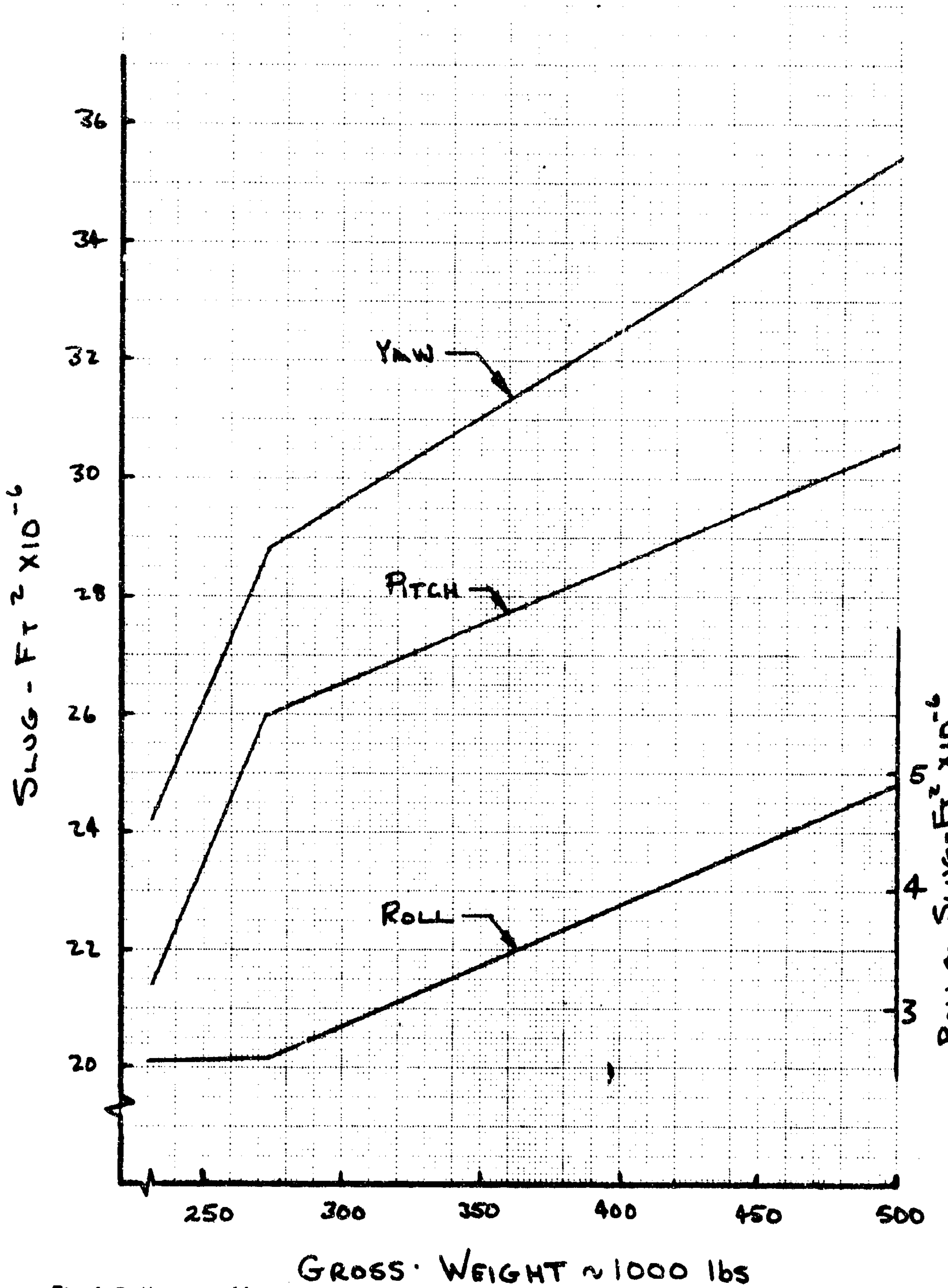


Fig. 6–7 Moments of Inertia

7.0 AIRFRAME

7.1 CONSTRUCTION AND MATERIALS

The structural design concepts and methods of analysis for the SCAT 15F-B7 are consistent with those used for the Boeing supersonic transport. This study takes advantage of improvements in structural technology presented in Phase II-A.

Skin-stringer construction of Ti 8-1-1 alloy material is used for the primary structure of the wing, body, canard, and empennage components. Material properties used are the same as those for the Phase II proposal (Reference D6-8680-6, Volume VI-A, Table 3-A).

A polyimide bonded honeycomb structure is used for secondary structures such as strake, and leading and trailing edge surfaces. Allowables for this type of construction are the same as those used for the Phase II-A report and are shown in D6-8680-6, Fig. 7-11.

The primary material used for the main and nose gear structure is 4340 M vacuum remelt steel, heat treated to 270-330 ksi. Reference page 8-37d of D6-2400-10, Volume A-IV for allowables, and D6-17640 for justification of material selection.

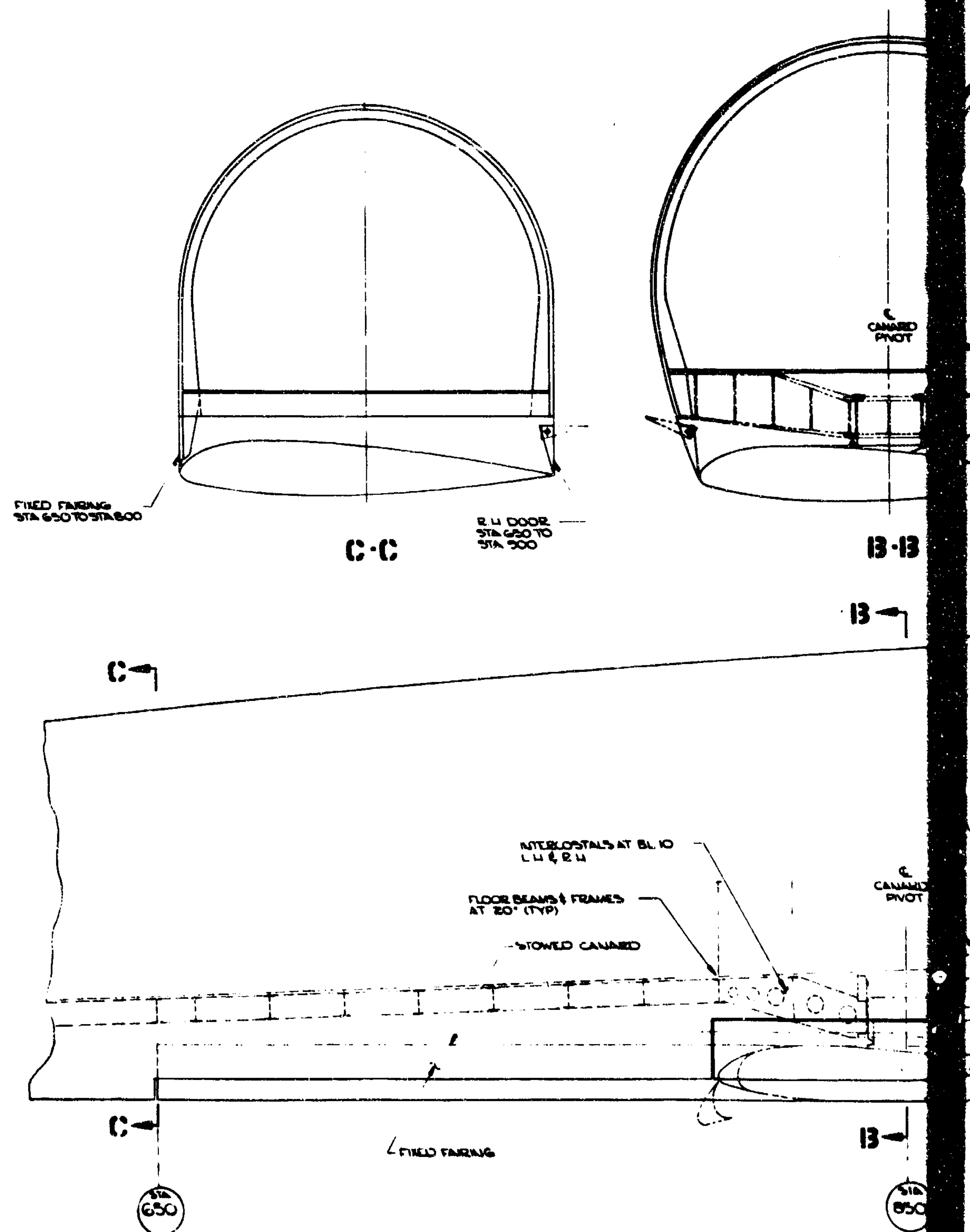
Figure 4-4 (Section 4.0) shows the wing structural arrangement consisting of skin-stringer construction with 27-inch rib spacing for the primary beam. The strake has a honeycomb surface with 30-inch rib spacing. The strake loads are carried through the body frames at 60-inch intervals.

The general arrangement of the canard support structure is shown in Fig. 7-1. Loads are transferred from a tube imbedded in the canard through two teflon bearings to the body support structure. Vertical and side loads are transferred through the floor beams at body stations 840 and 860 to the monocoque structure. Drag loads are transferred to the fuselage floor through intercostals at BBL 20 on each side of the bearing support structure.

The mechanism for rotating the canard and extending the flaps and slats is shown in Fig. 7-2. The actuation system for rotating the canard from the stowed to the operating position is a ball-screw driven by a differential gearbox. The gearbox is powered by three hydraulic motors, each of which is supplied by a separate hydraulic system. The leading edge slats and trailing edge flaps on the canard are actuated with ball-screws powered by drive shafts through the canard pivot from a single gearbox located in the fuselage. The gearbox is powered by two hydraulic motors, each of which is supplied by a separate hydraulic system.

7.2 CRITERIA

Design loads criteria for the structural design are consistent with criteria presented in Section 4, D6-2400-10, Volume A-IV, of the


FIXED FAIRING STA 650 TO STA 800
R.H DOOR STA 650 TO STA 500
C-C
℄ CANARD PIVOT
B-B
INTERCOSTALS AT BL 10 LH & RH
FLOOR BEAMS & FRAMES AT 20" (TYP)
STOWED CANARD
FIXED FAIRING
STA 650

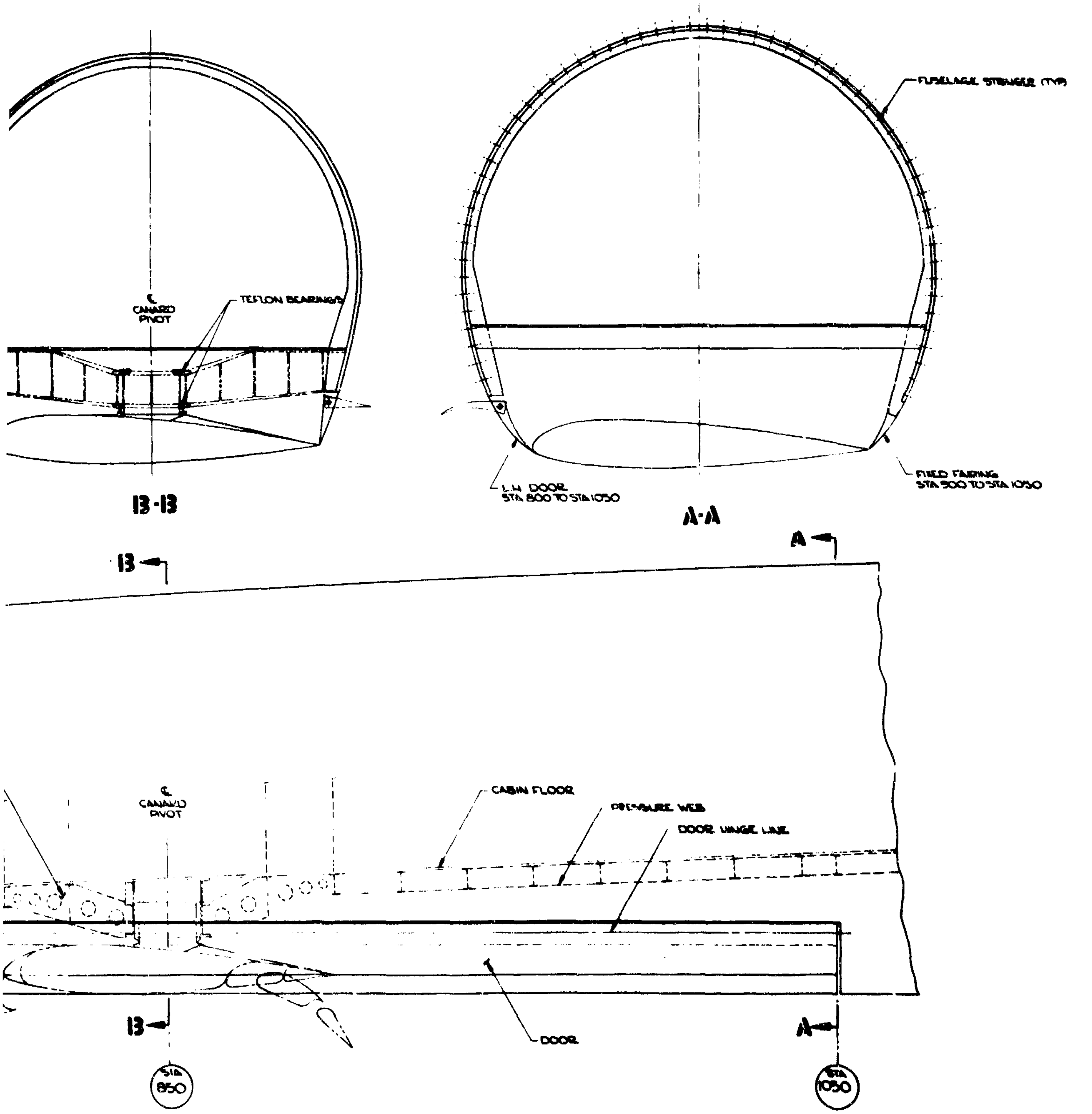
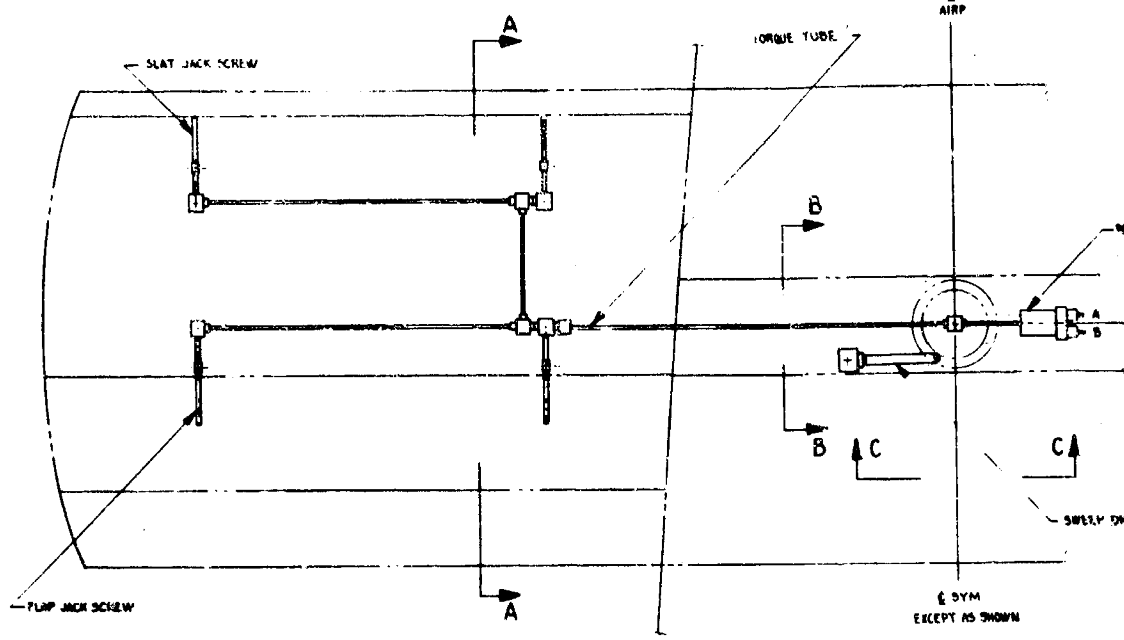
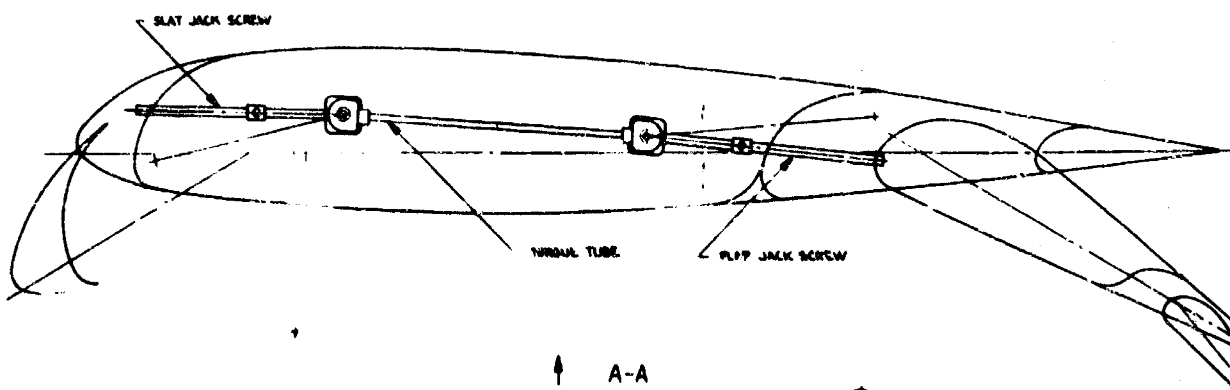


Fig. 7-1 Canard Support Structure

2



PLAN VIEW
1/10 SIZE



A-A
1/4 SIZE

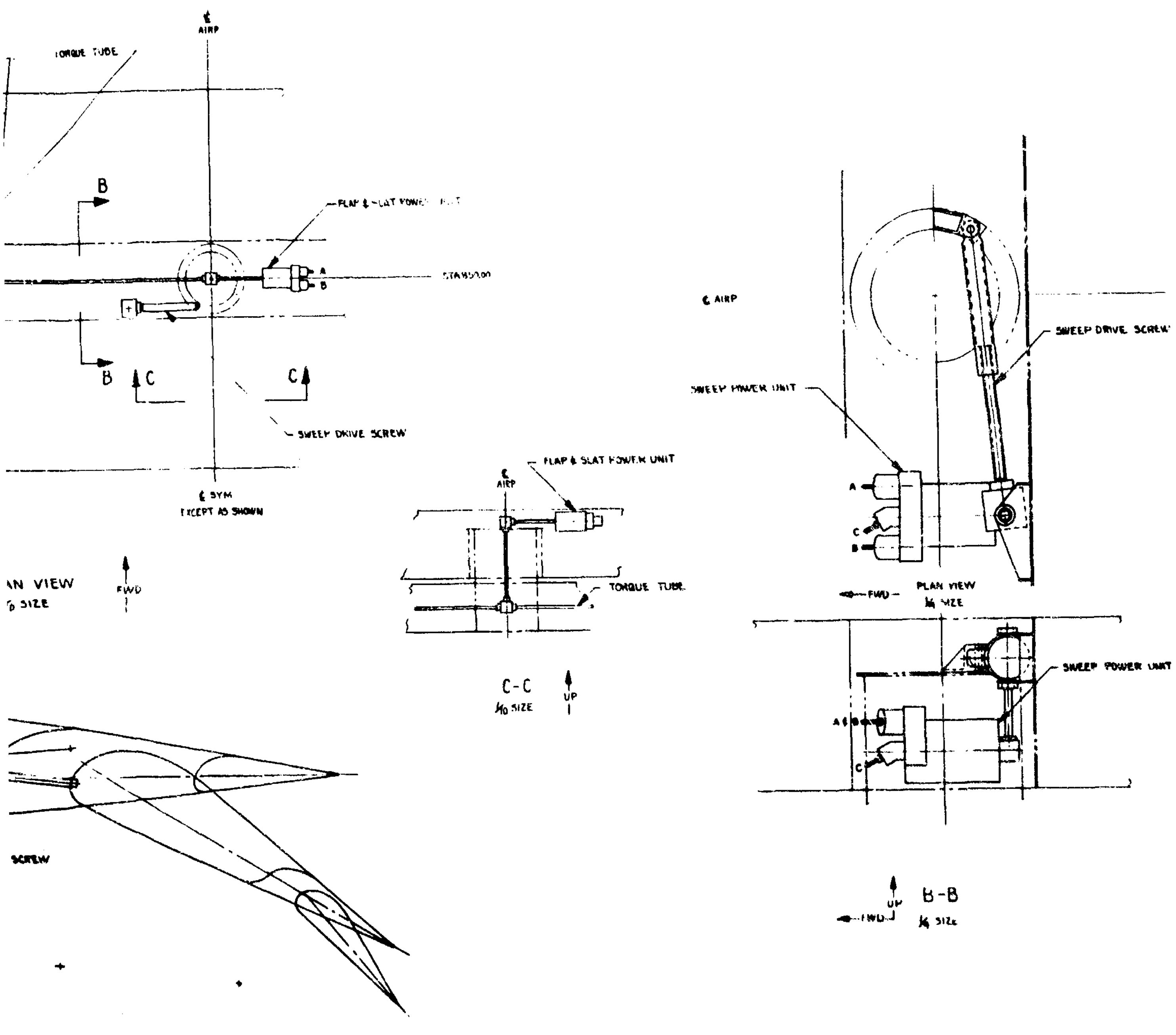


Fig. 7-2 Canard Mechanism

Phase I proposal. Modifications are made only where required to conform to configuration and mission profile differences.

The structural design flight envelope for the SCAT 15F-B7 is shown in Fig. 7-3.

The variation of design gross weight with altitude is shown in Fig. 7-4. Other structural design gross weights for the SCAT 15F-B7 are as follows:

Maximum Design Taxi Weight	500,000 pounds
Maximum Design Flight Weight at S.L.	
Flaps Down	497,000 pounds
Flaps Up	495,000 pounds
Maximum Design Landing Weight	340,000 pounds

Flight conditions influencing the structural design of major components are shown on the V-n diagrams in Fig. 7-5. Positive gust load factor variation with gross weight is shown in Fig. 7-6. A dynamic magnification factor of 1.2 is applied to Δ_n for design of wing and body structure. This factor is not included in Fig. 7-6.

7.3 LOADS

Figure 7-7 shows the wing load reference axis and the box beam structural arrangement for the SCAT 15F-B7 that is subjected to the net loads applied on the wing area aft of body station 2380. Net wing shear, moment, and torsion along the load reference axis is shown in Figs. 7-8 and 7-9 for the two most critical conditions. Elastic wing airload distribution is based on the wing stiffness shown in Fig. 7-10.

Figure 7-11 gives a comparison of the relative wing cover panel weight for the critical design conditions. It clearly shows that the supersonic condition is critical for the upper and lower wing surface. The wing surfaces at the fin attachment point and for a distance of 50 inches inboard of the fin joint are critical for fin gust conditions which are about 20 percent more critical than the supersonic condition at the fin joint. This local effect is not shown in Fig. 7-11. Wing cover panel allowables used for determining the required wing structural material are the same as those used in Phase I (Reference D6-2400-10, Volume A-IV, Book 2, Fig. 8-4).

Fuselage shears and moments are shown in Figs. 7-12 and 7-13. The dynamic landing condition values shown are based on a preliminary estimate of magnification factors obtained using data from the 733-290 with corrections for change in body length. Fuselage structural panel allowables are the same as those used in Phase I proposal (Reference D6-2400-10, Figs. 8-16 through 8-19).

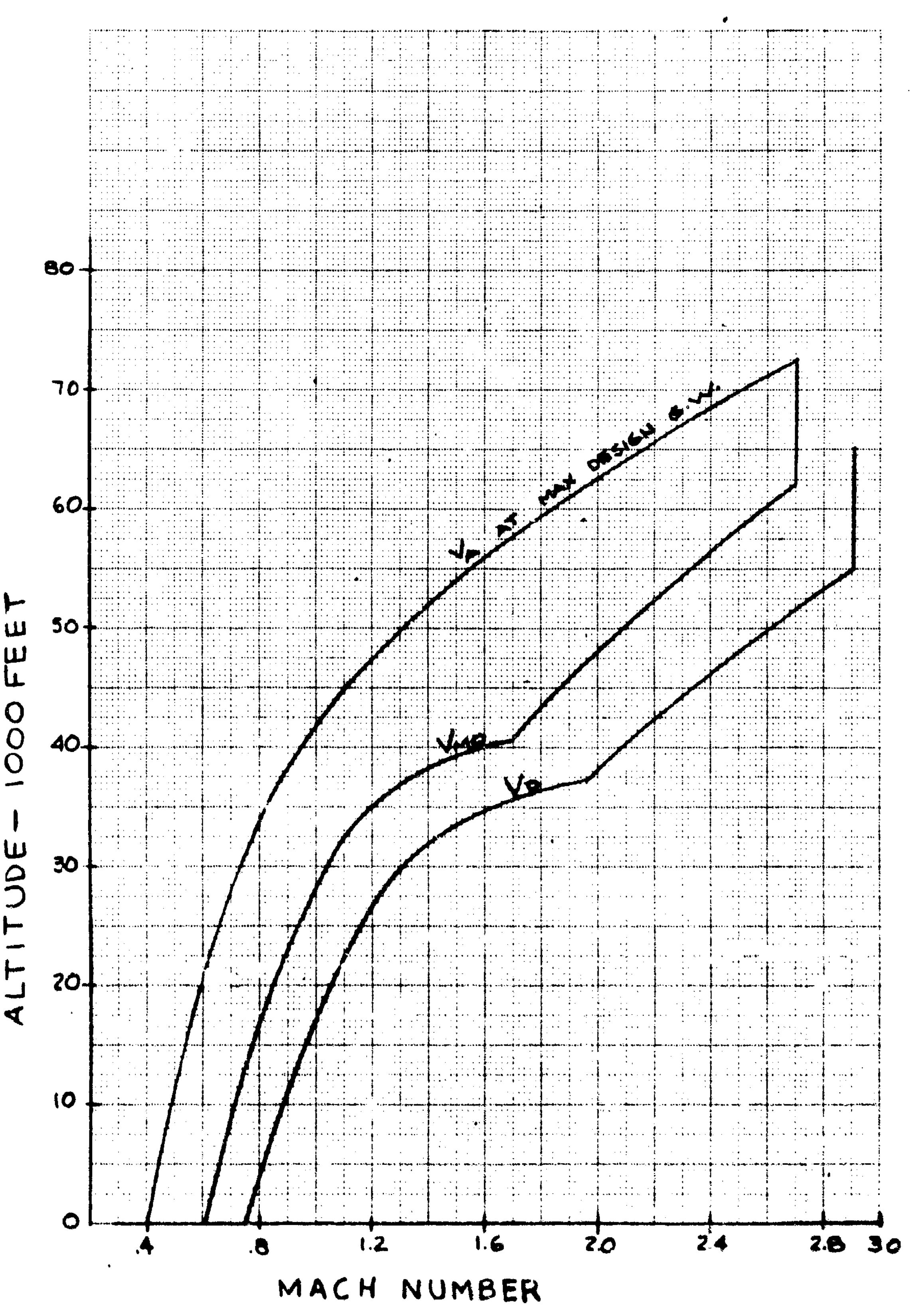


Fig. 7-3 Structural Design–Speed Altitude Diagram

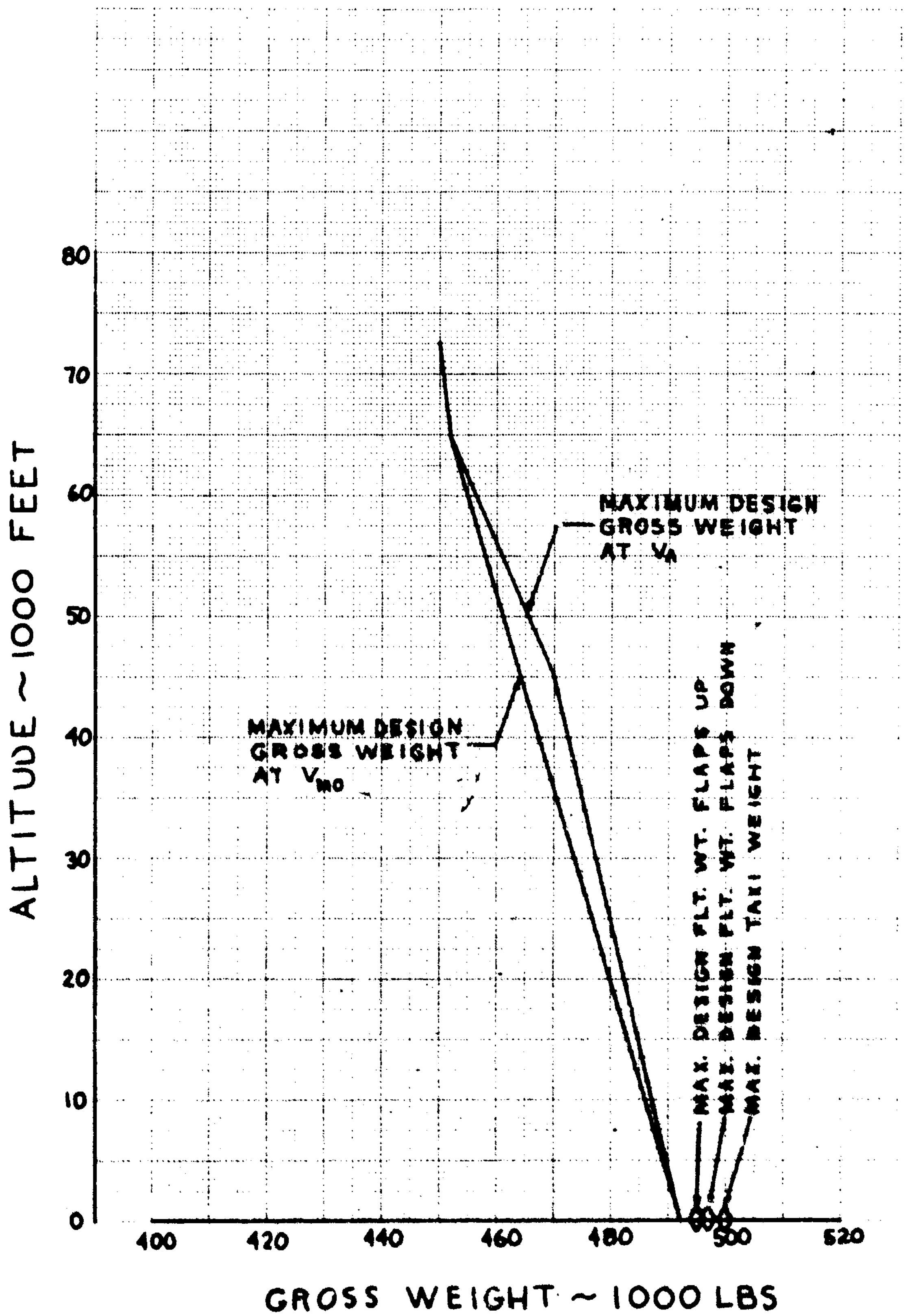


Fig. 7-4 Maximum Design Gross Weight

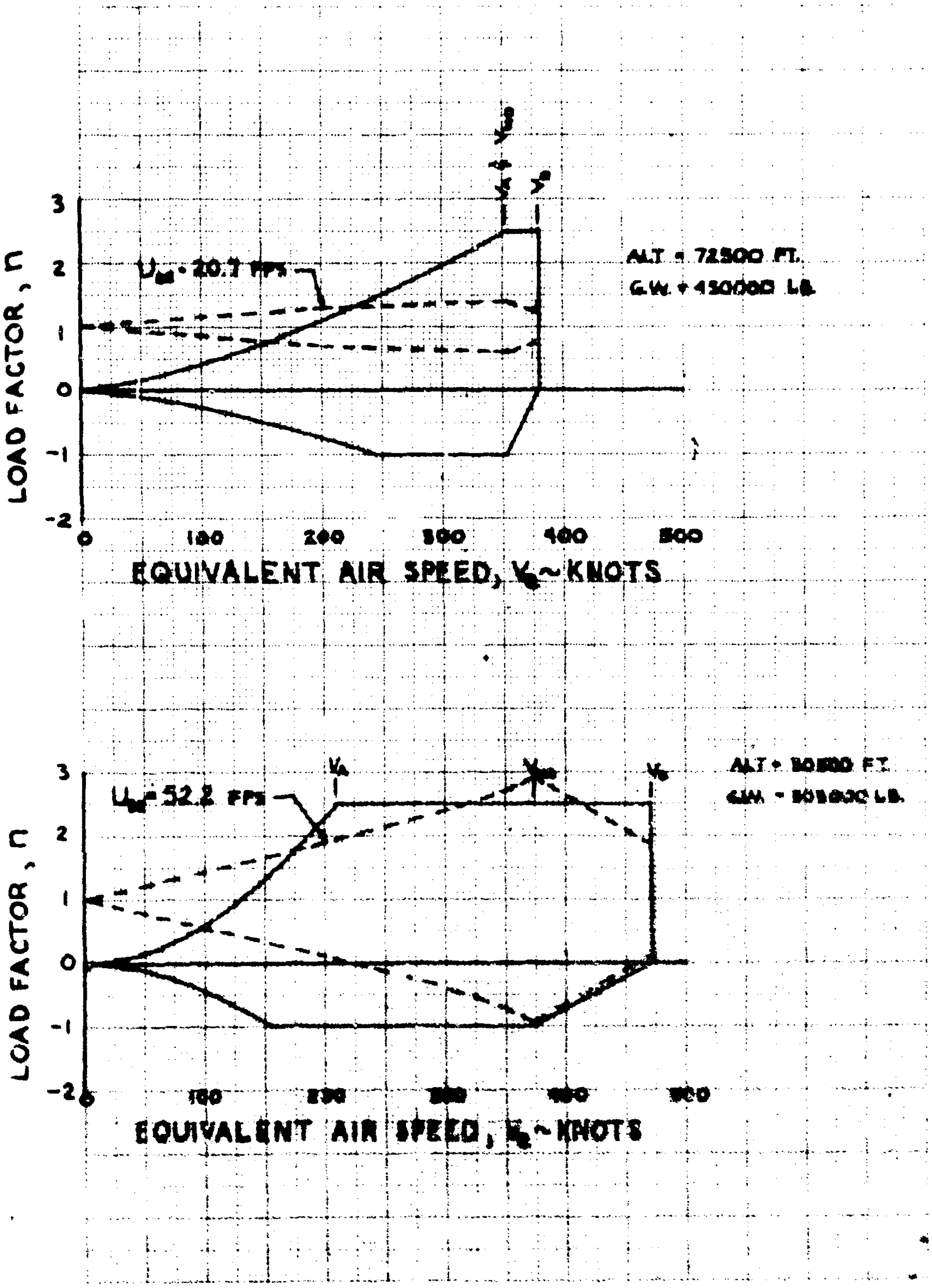


Fig. 7-5 V-n Diagrams

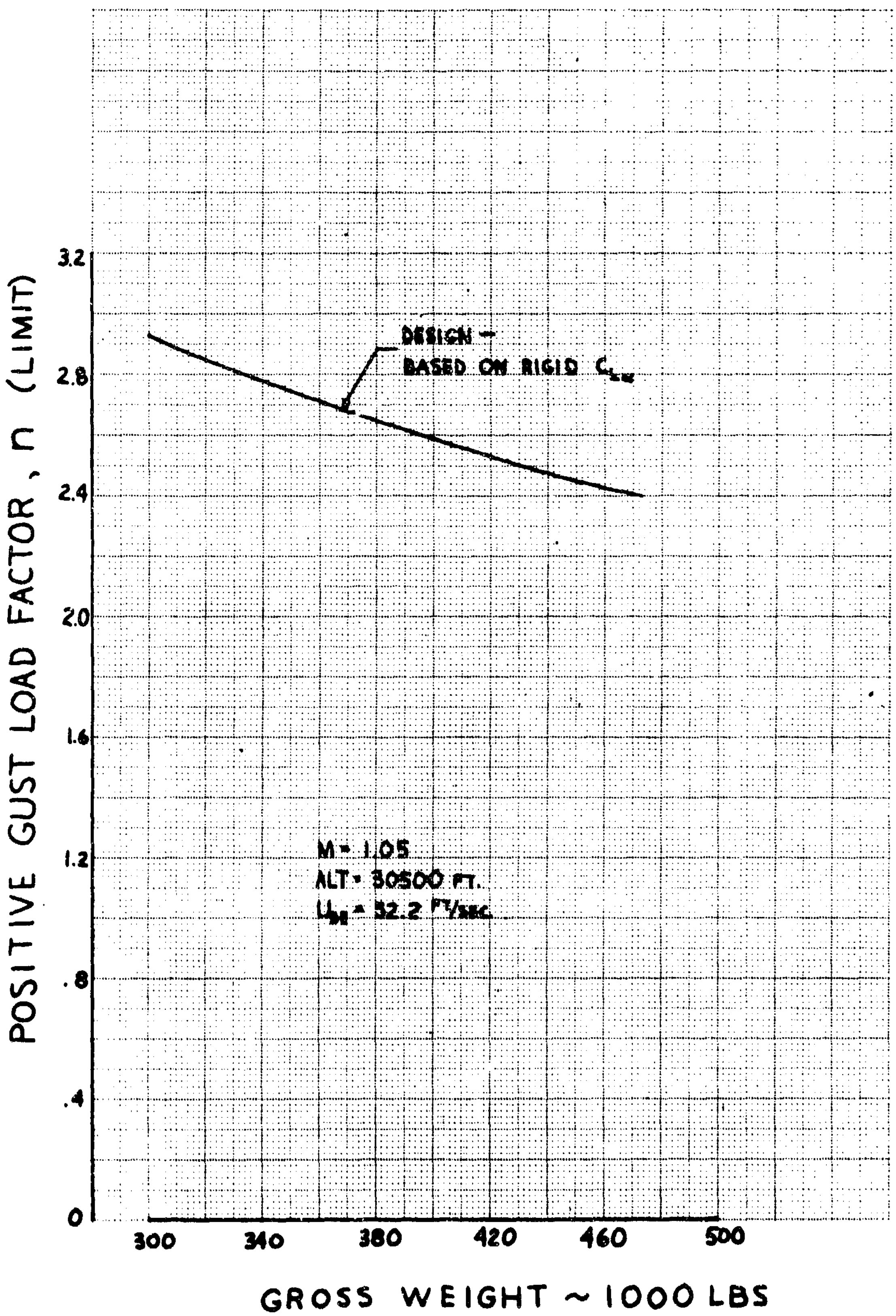


Fig. 7-6 Positive Gust Load Factor

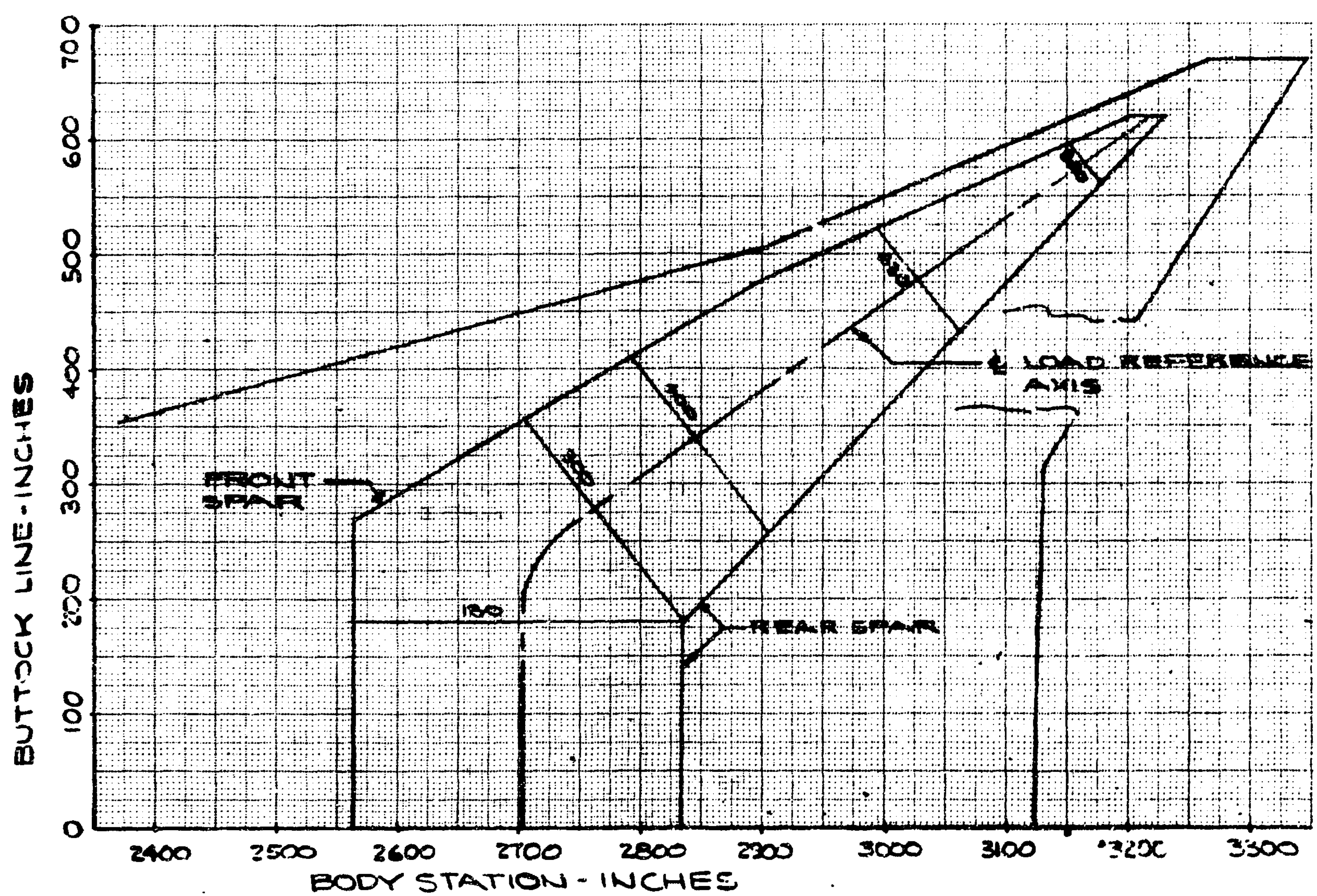


Fig. 7-7 Load Reference Axis Diagram

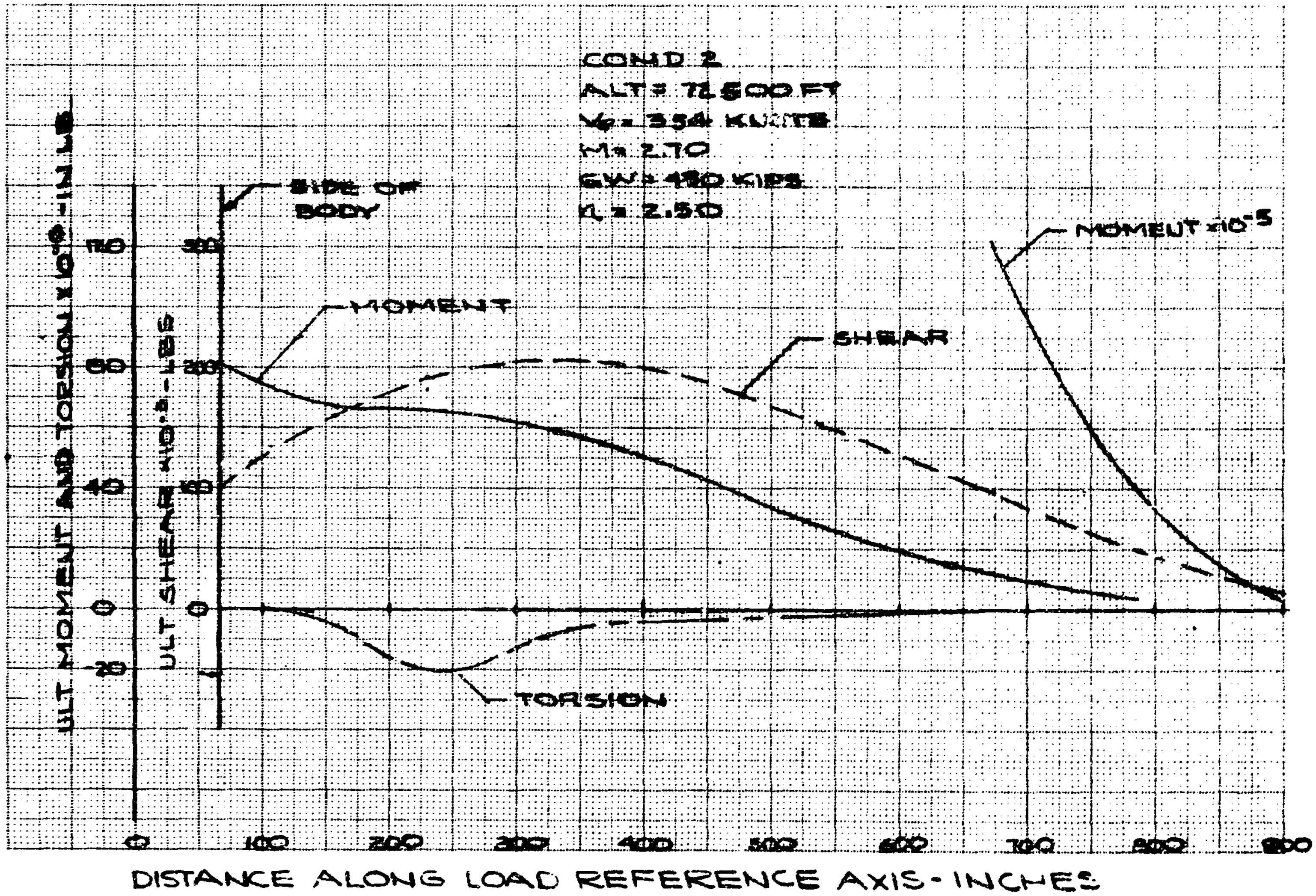


Fig. 7-8 Ultimate Wing Loads – Supersonic Maneuver

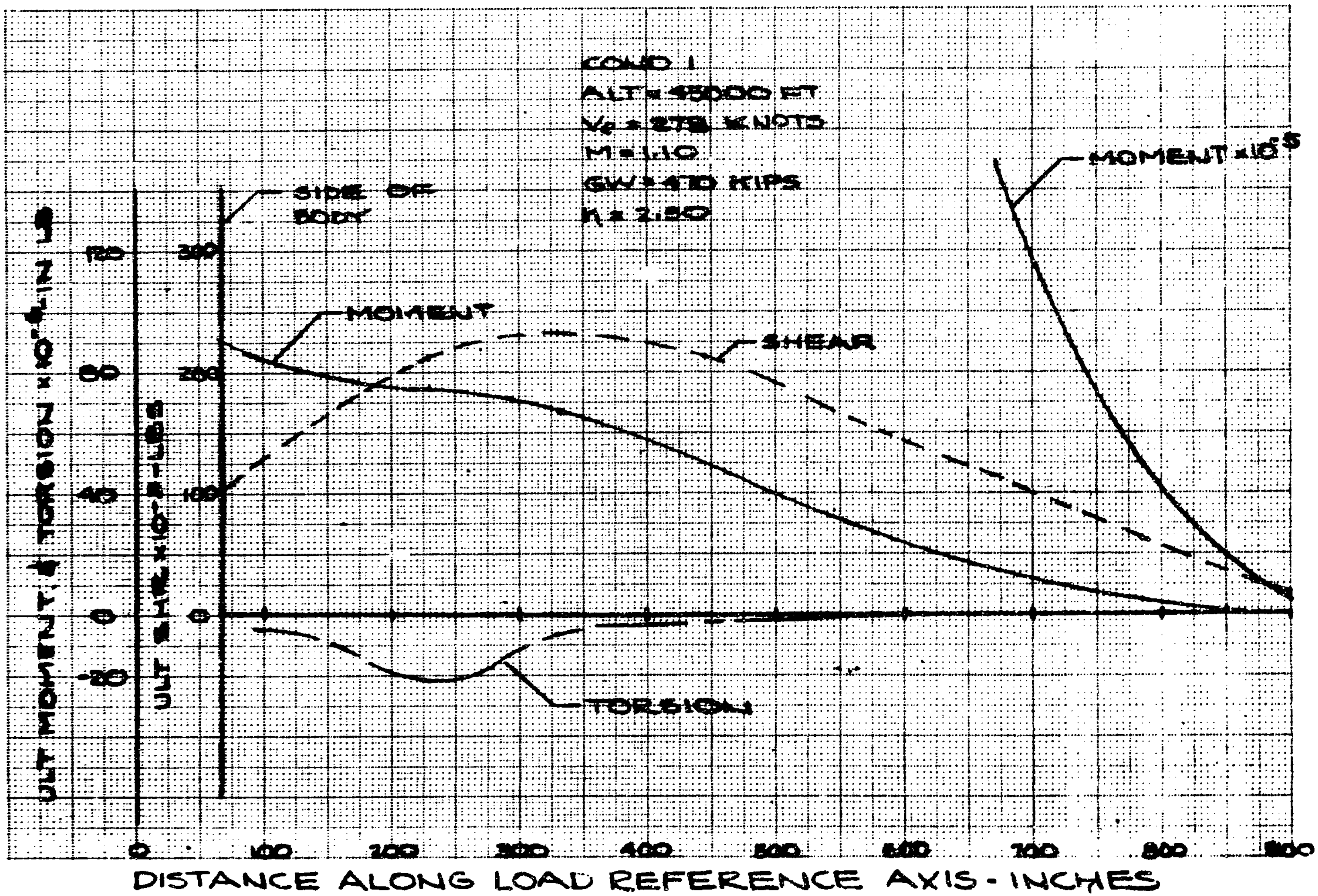


Fig. 7-9 Ultimate Wing Loads – Transonic Maneuver

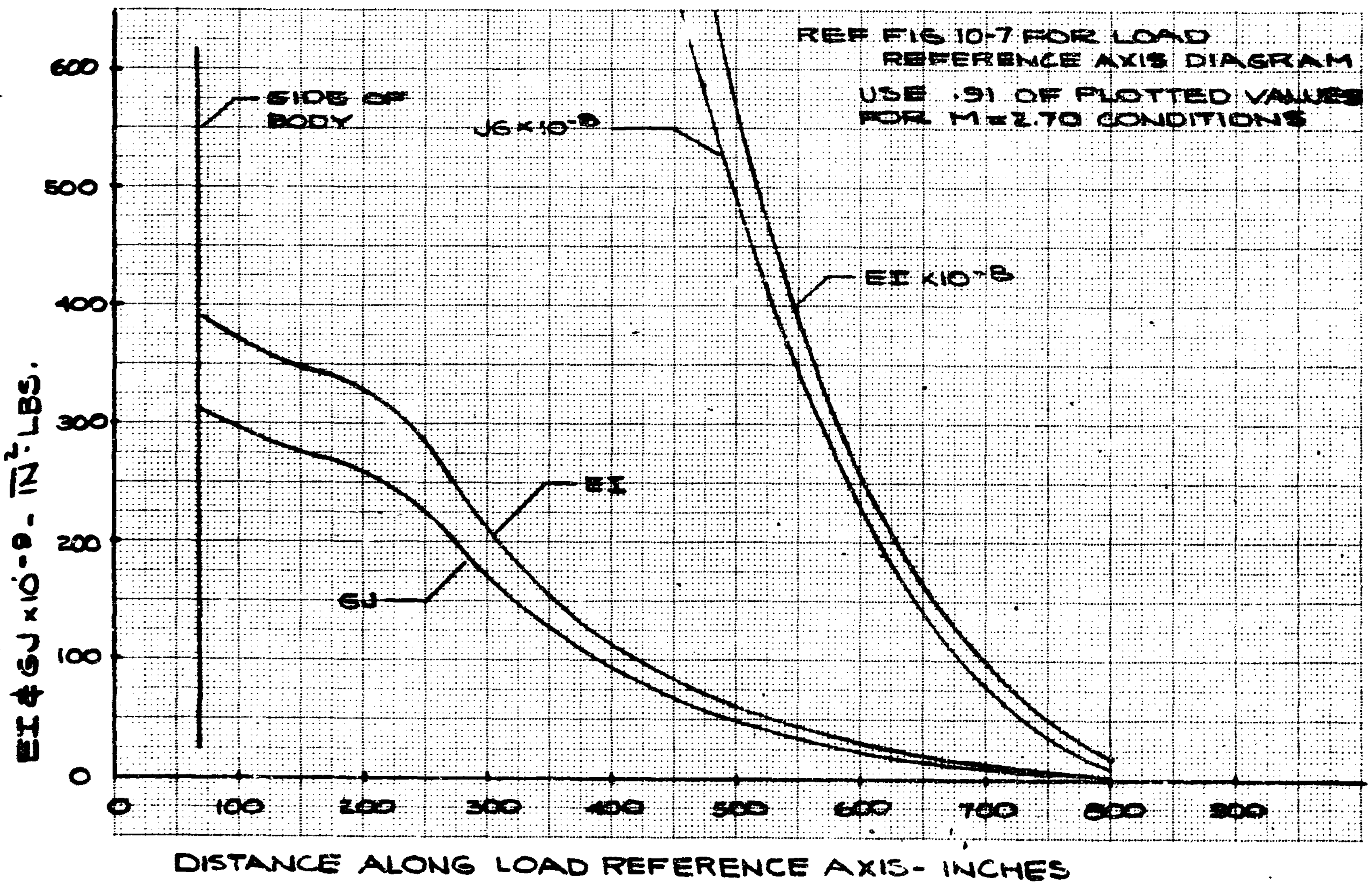


Fig. 7-10 Wing Bending & Torsional Stiffness

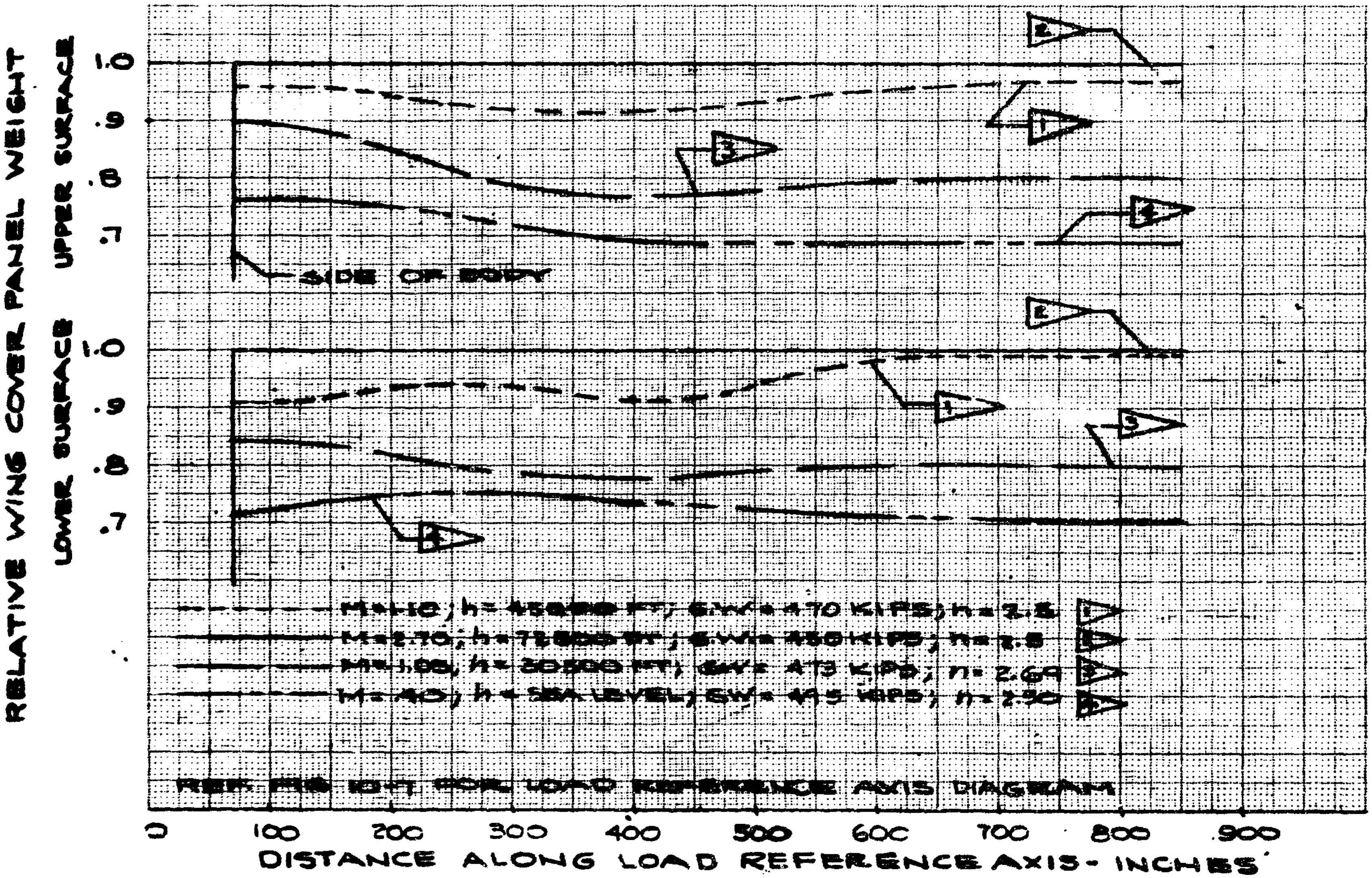


Fig. 7-11 Comparison of Wing Design Conditions

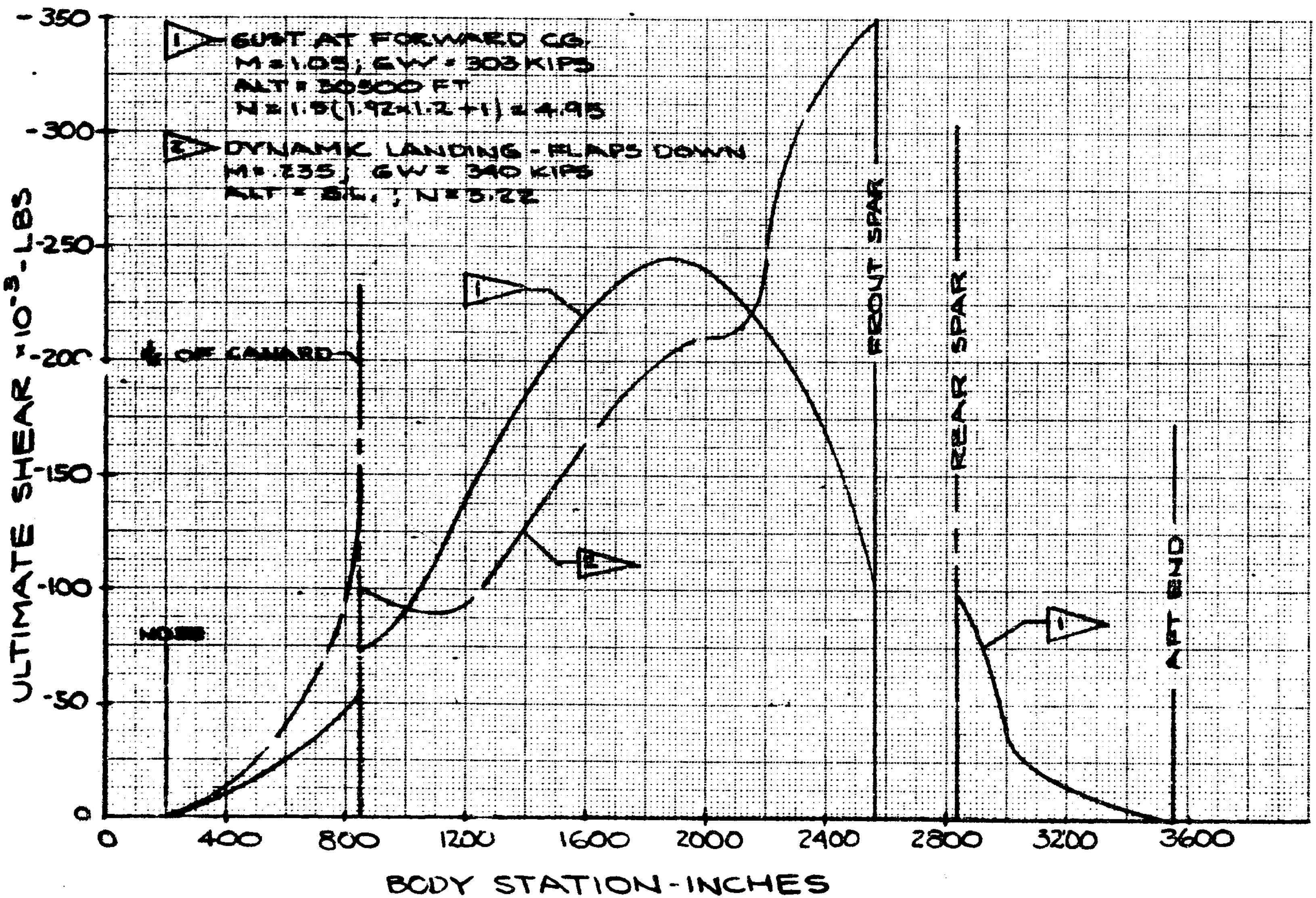


Fig. 7-12 Ultimate Fuselage Shear

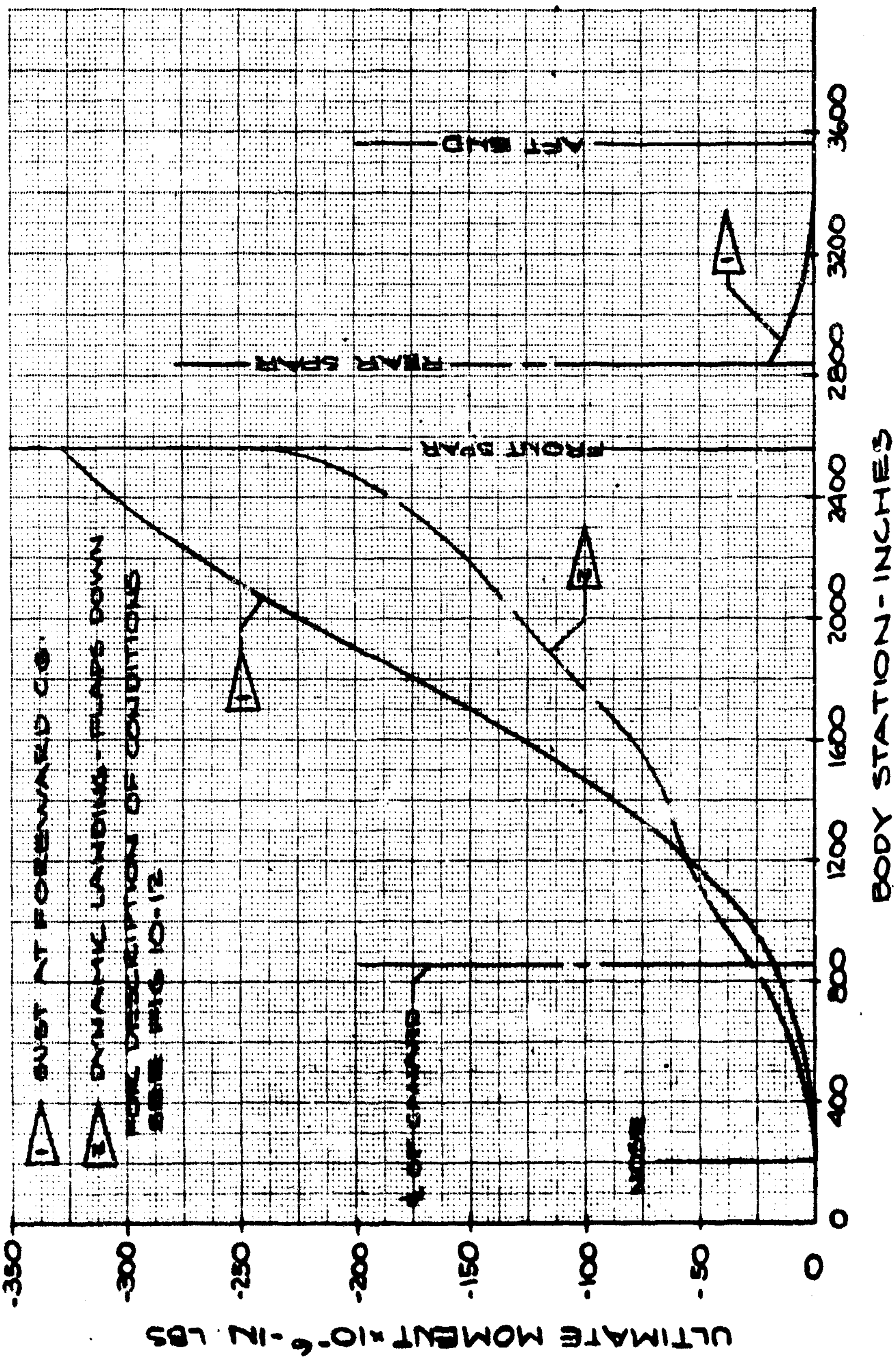


Fig. 7-13 Ultimate Fuselage Moment

The preliminary ultimate design canard load is 100 kips and is based on the following data:

Max C_L Canard = 2.5

M = .3 at sea level

Exposed Canard Area = 200 feet^2

7.4 FLUTTER EVALUATION

Evaluation of the SCAT 15F configuration revealed several areas where flutter problems may be anticipated.

7.4.1 Wing Tip-elevon (Outboard of Vertical Tail)

The primary structure terminates a considerable distance short of the elevon tip, and tapers in such a manner that the torsional rigidity at the outboard elevon hinge fitting appears to be essentially zero. This is a potentially unsatisfactory situation which may result in a coupled wing torsion - elevon rotation flutter speed below the design speed. To correct this condition, additional torsional rigidity would be required in the wing tip region.

7.4.2 Engine Location

The engine centers of gravity are far aft of the main wing box. This is particularly significant in the case of the outboard engines, which are outboard of the wing mid semi-span. This condition may result in unfavorable wing box bending-torsion coupling with attendant adverse flutter characteristics.

7.4.3 The Vertical Tail Location

The vertical tail, being located near the wing tip with its CG aft of the wing box, presents a "T-tail" type coupled fin-wing flutter situation. In the event that detailed analysis revealed a flutter speed deficiency, a sizeable stiffness increase (with an associated weight penalty) might be required to achieve adequate flutter margins.

7.4.4 Control Surface Transonic Buzz

Achieving sufficient rotational and/or torsional rigidity for the prevention of buzz on the rudder and outboard elevon may be difficult, particularly in light of the long spans and small thicknesses of these surfaces.

8.0 MANUFACTURING FEASIBILITY

The construction of the SCAT 15F-B7 is quite similar to the 733-290 except for differences in the configurations. The feasibility as presented in D6-8680-6 "Airframe Design," Section 6, and D6-2400-4, "Preliminary Production Planning," would also apply to this airframe.

The area of major difference affecting manufacturing producibility is the wing. On a prototype the increase in manufacturing manhours to build a larger wing, and the extensive manhours and flow time required to join the outboard wings to the inboard wing of the SCAT 15F-B7, is offset by the extensive tooling required to build the more complex, heavier members of the Model 733-290 wings. However, for a production program, the additional recurring manhours used for building and joining the SCAT 15F-B7 wing would increase unit costs.

Other manufacturing disadvantages are the increased flow time required for wing joining on the final assembly floor, the delay in sequencing the sealing and testing of wings until after wings are joined, the increased factory area requirements to accomplish wing joining in an earlier position to maintain schedules, and the increased support effort required to procure, manufacture, handle, and store the additional airplane details and components.

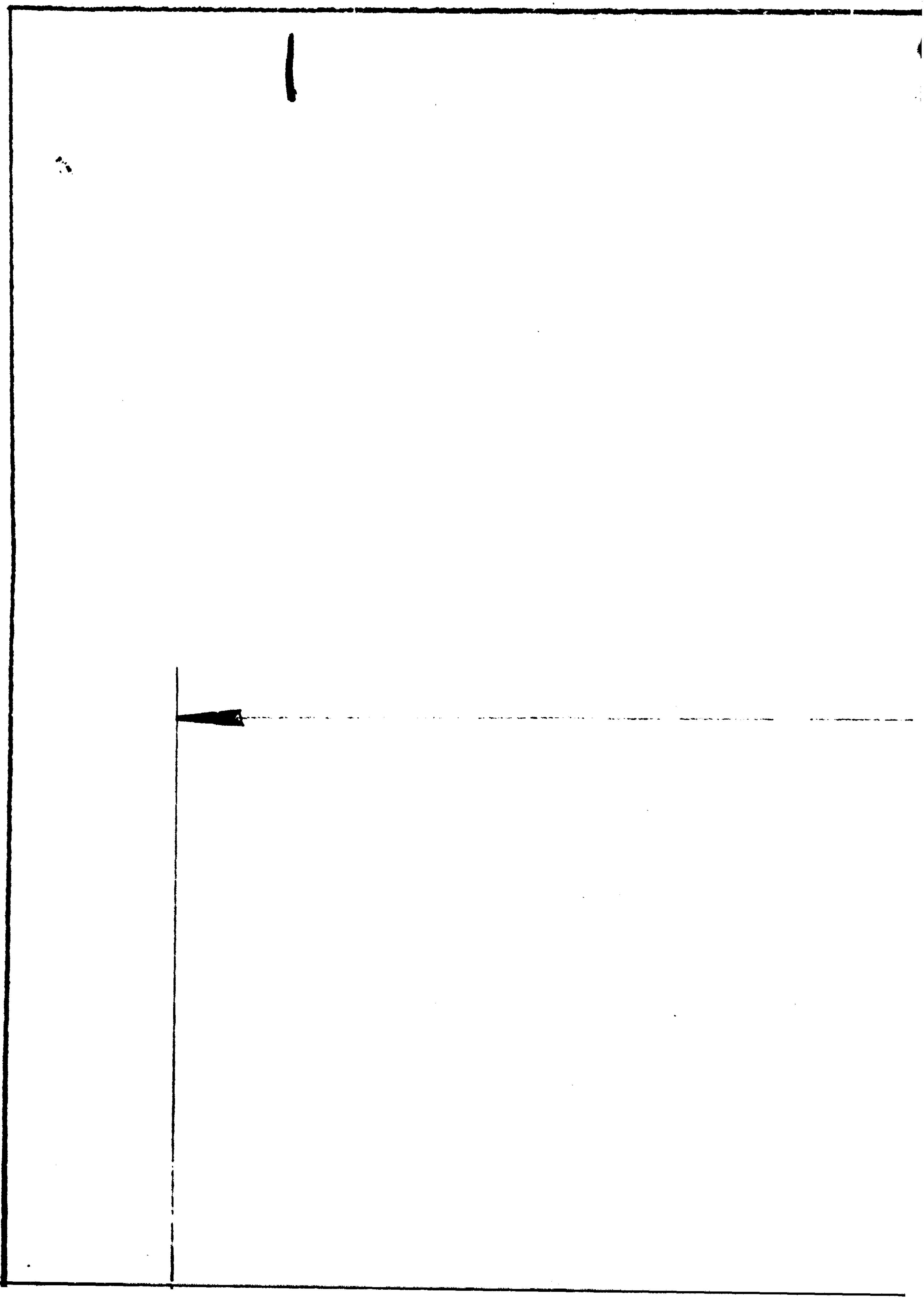
Since the wing is considered a "lifeline" (long lead) item in the manufacturing plan, the SCAT 15F-B7 airplane, as shown on the preliminary sketches, is less producible than the 733-290.

9.0 REFERENCES

3-1 Boeing Document D6-8680-5, Commercial Supersonic Transport Program, Phase II-A Comprehensive Report, November 1, 1964.

3-2 Boeing Document D6-7161, Turbulent Boundary Layer Flow Past a Smooth Adiabatic Flat Plate, 1961.

3-3 Sommer, Simon C. and Short, Barbara J., Free-Flight Measurements of Turbulent-Boundary-Layer Skin Friction in the Presence of Severe Aerodynamic Heating at Mach Numbers from 2.8 to 7.0, NACA TN 3391, March, 1955.



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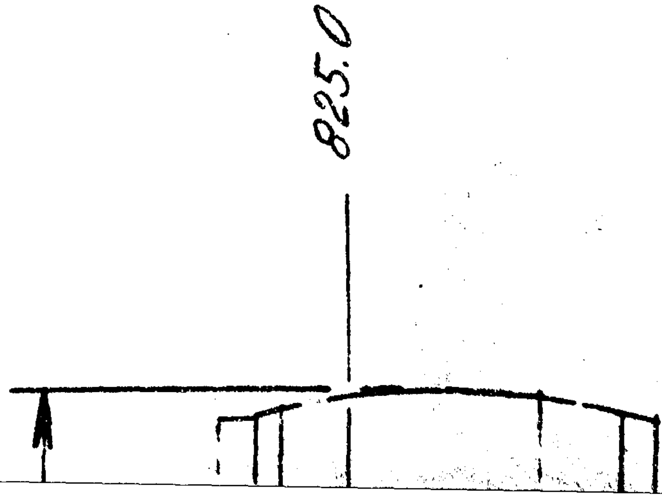
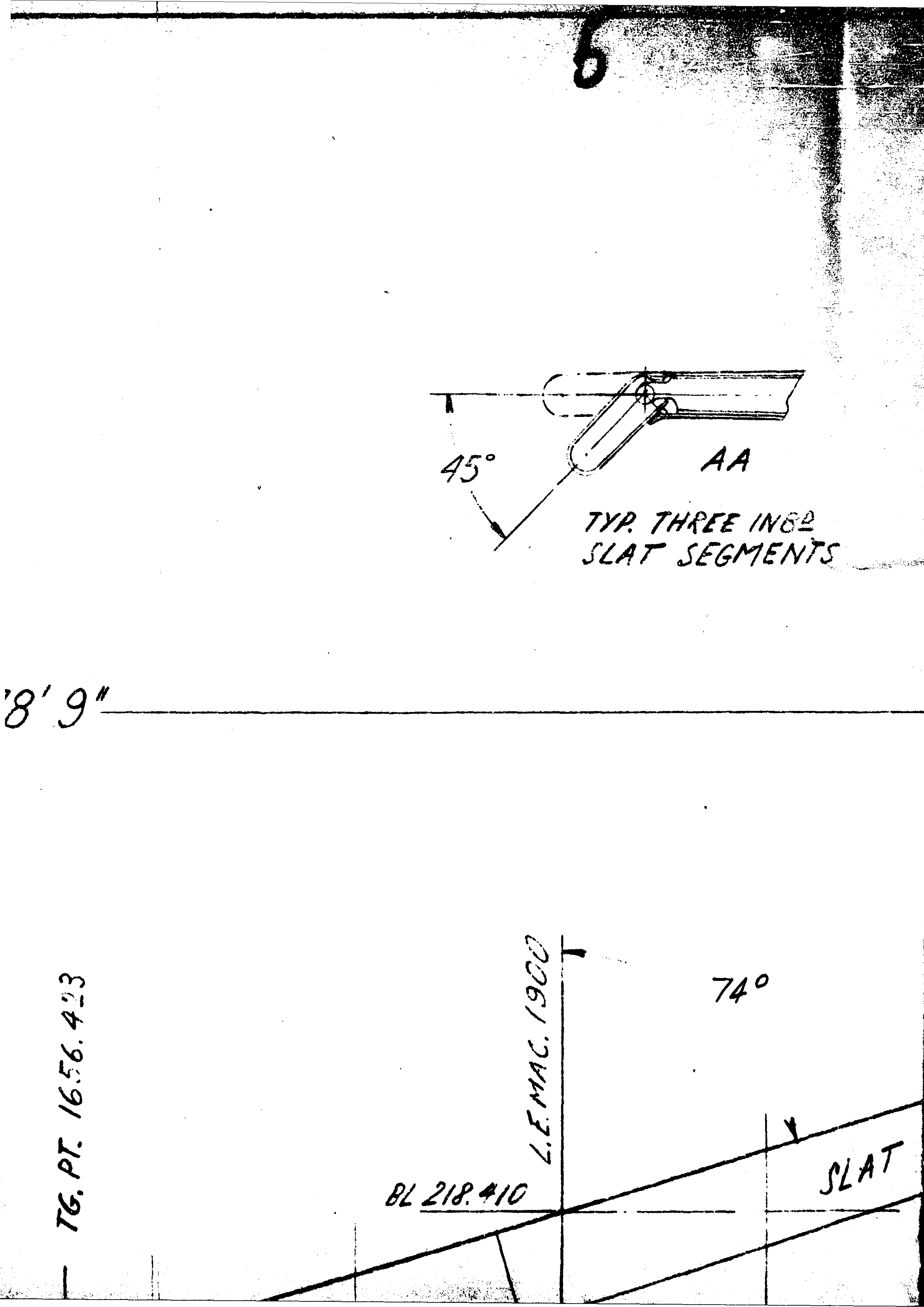


4

278' 9"

TG. PT. 16.56.423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45°
AA
TYP. THREE INBD
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SLAT
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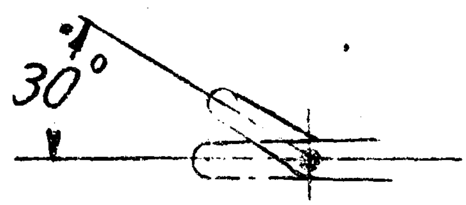
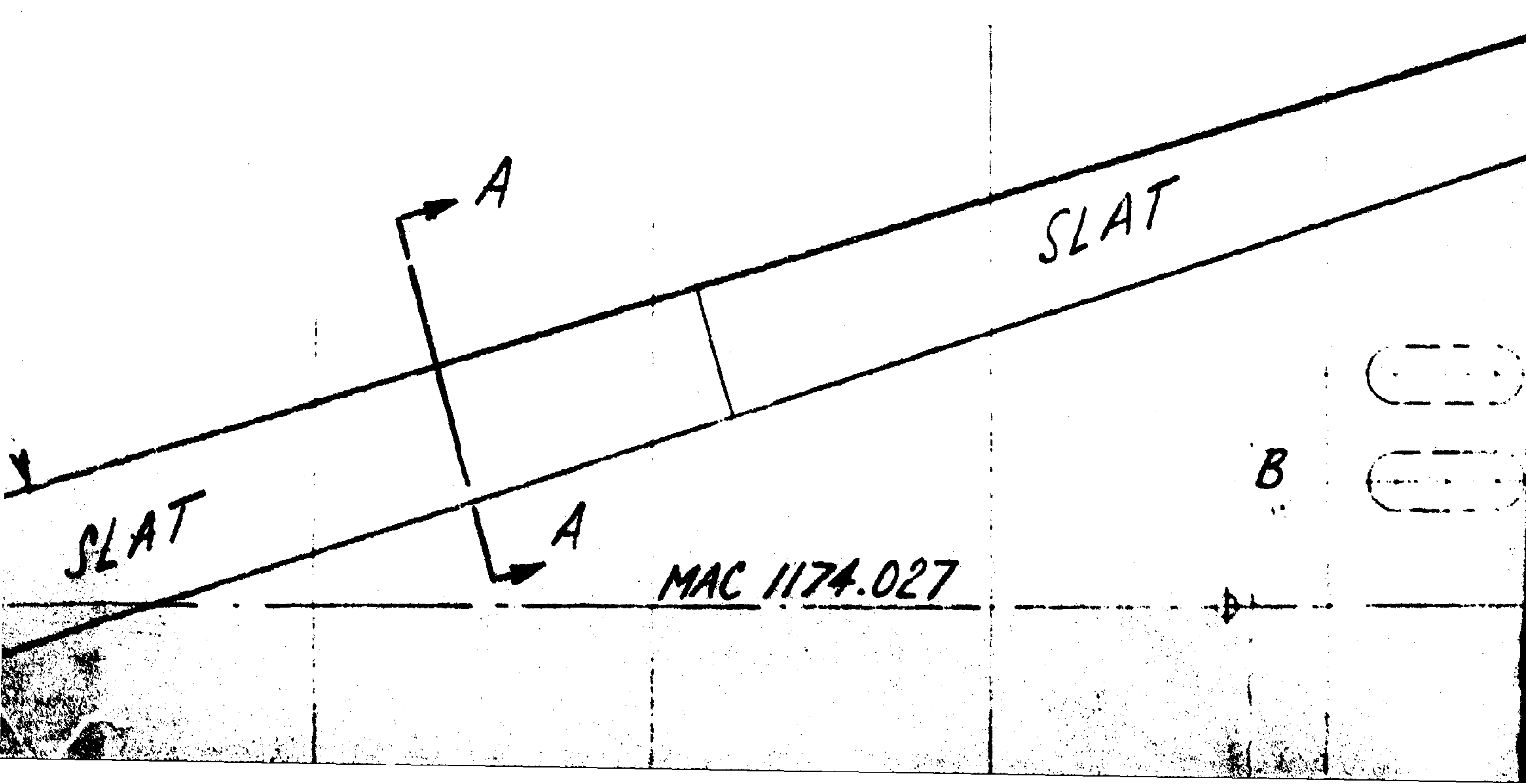
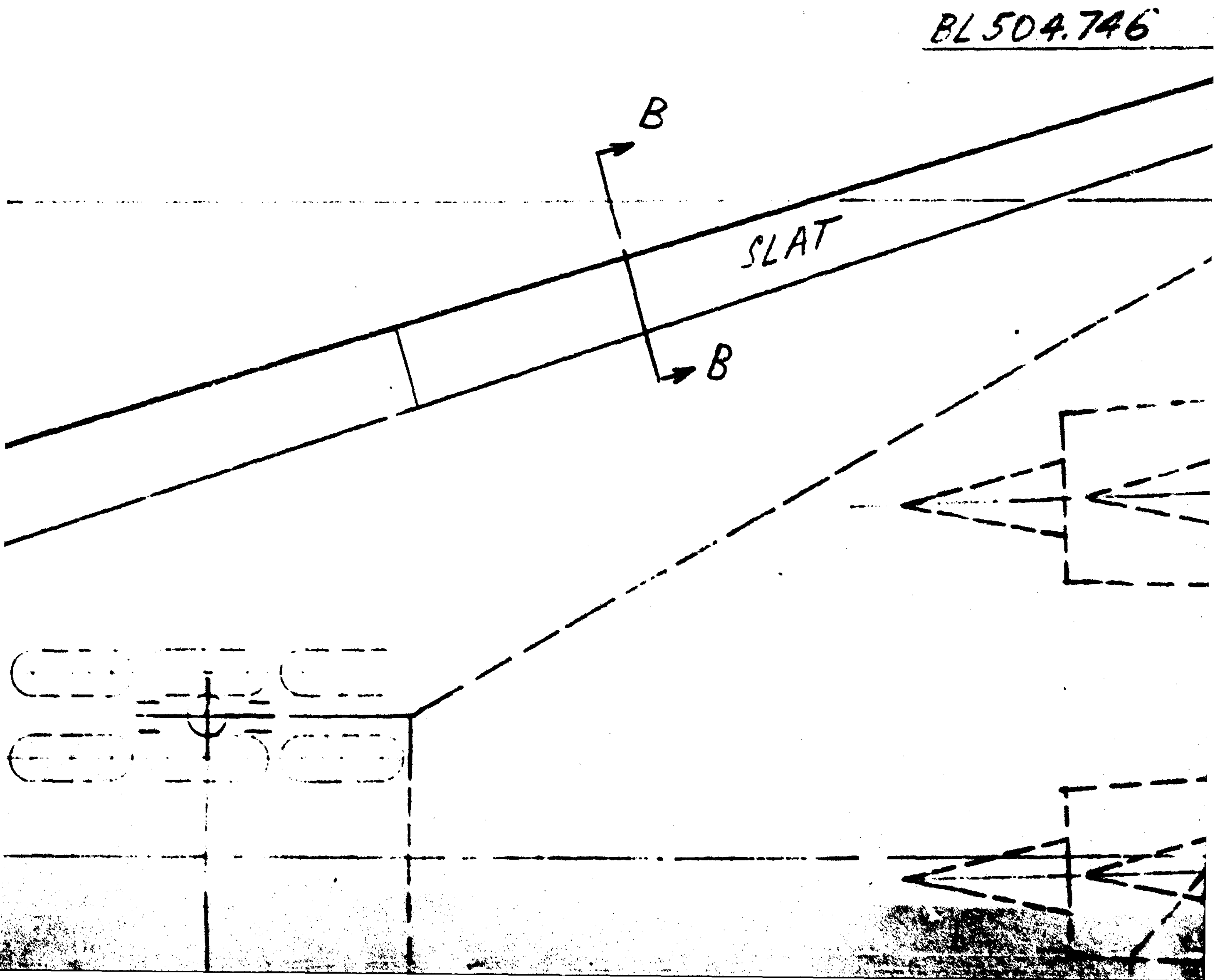
7



BB
OUTBD SEGMENT

NTS

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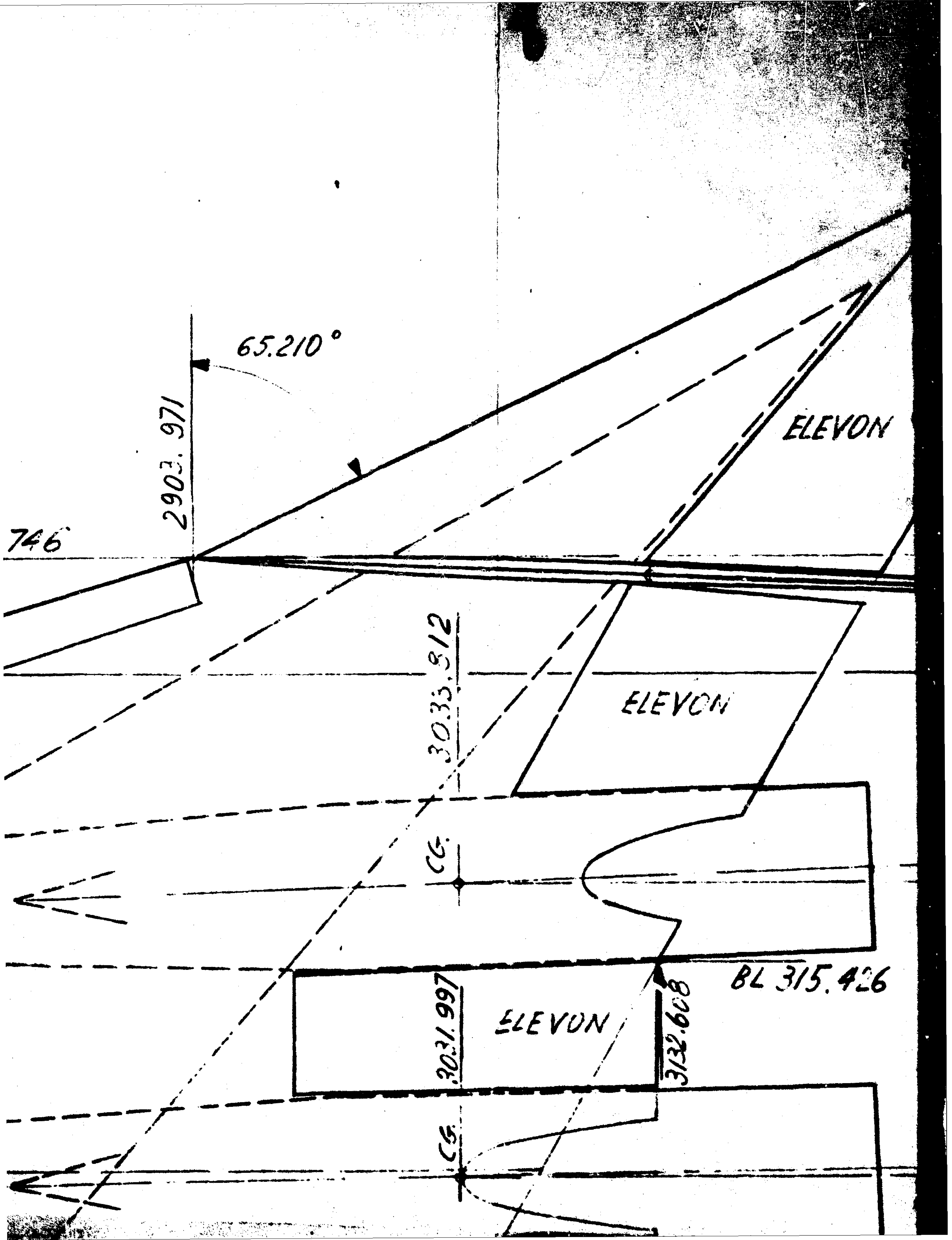
B
SLAT
B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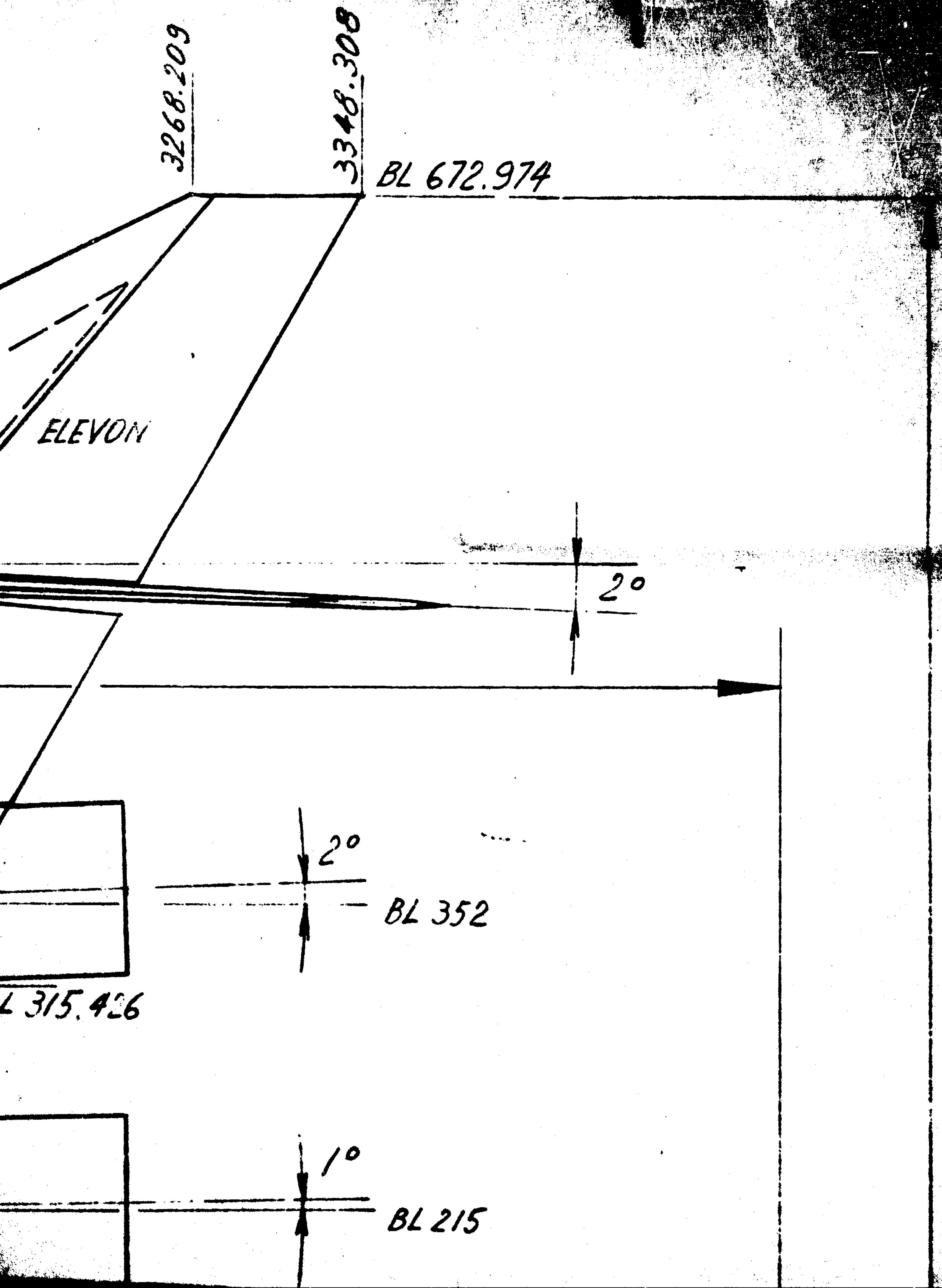
2903.971
746
ELEVON
ELEVON
CG.
ELEVON
3132.608
BL 315.426
CG.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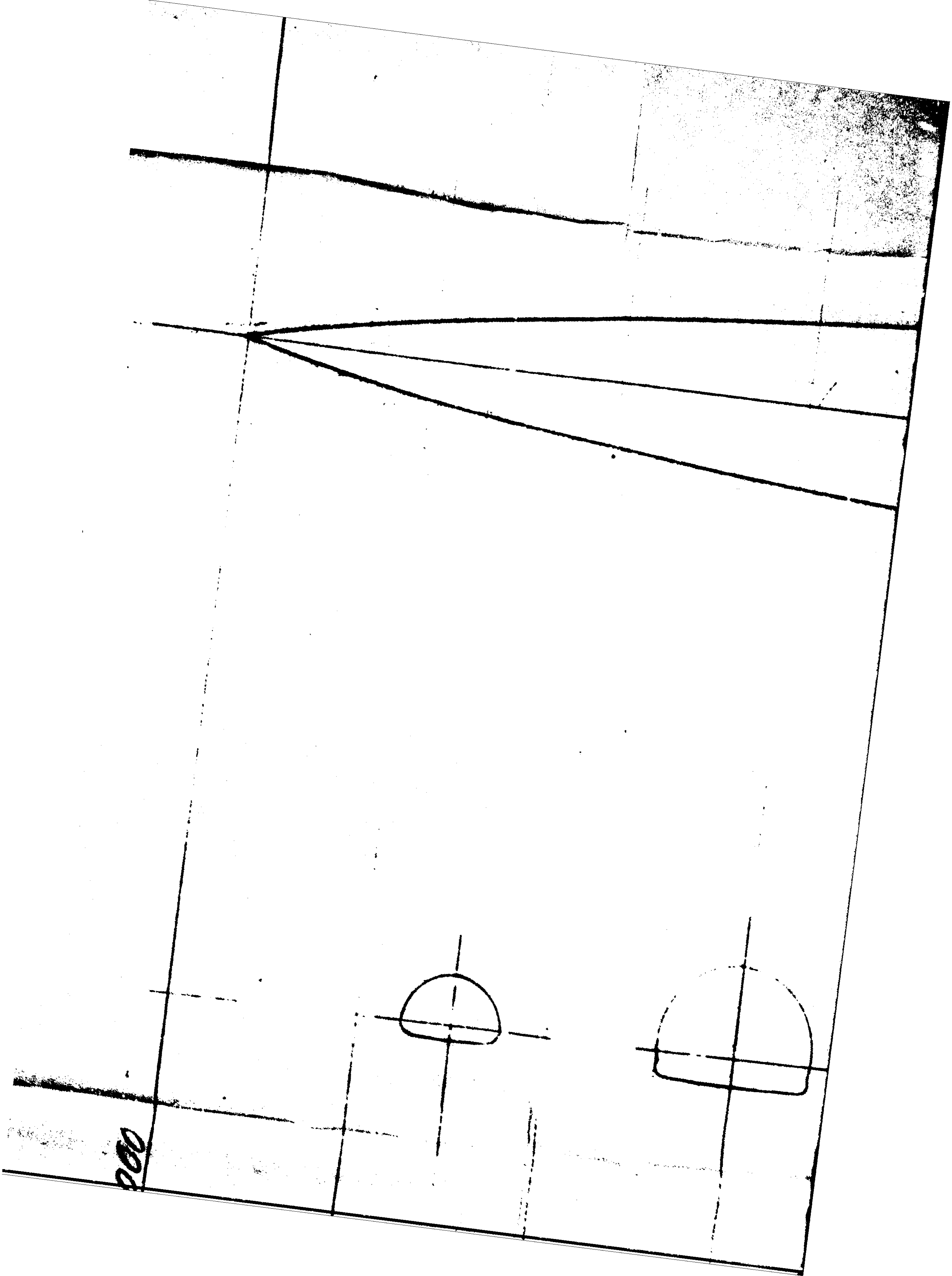
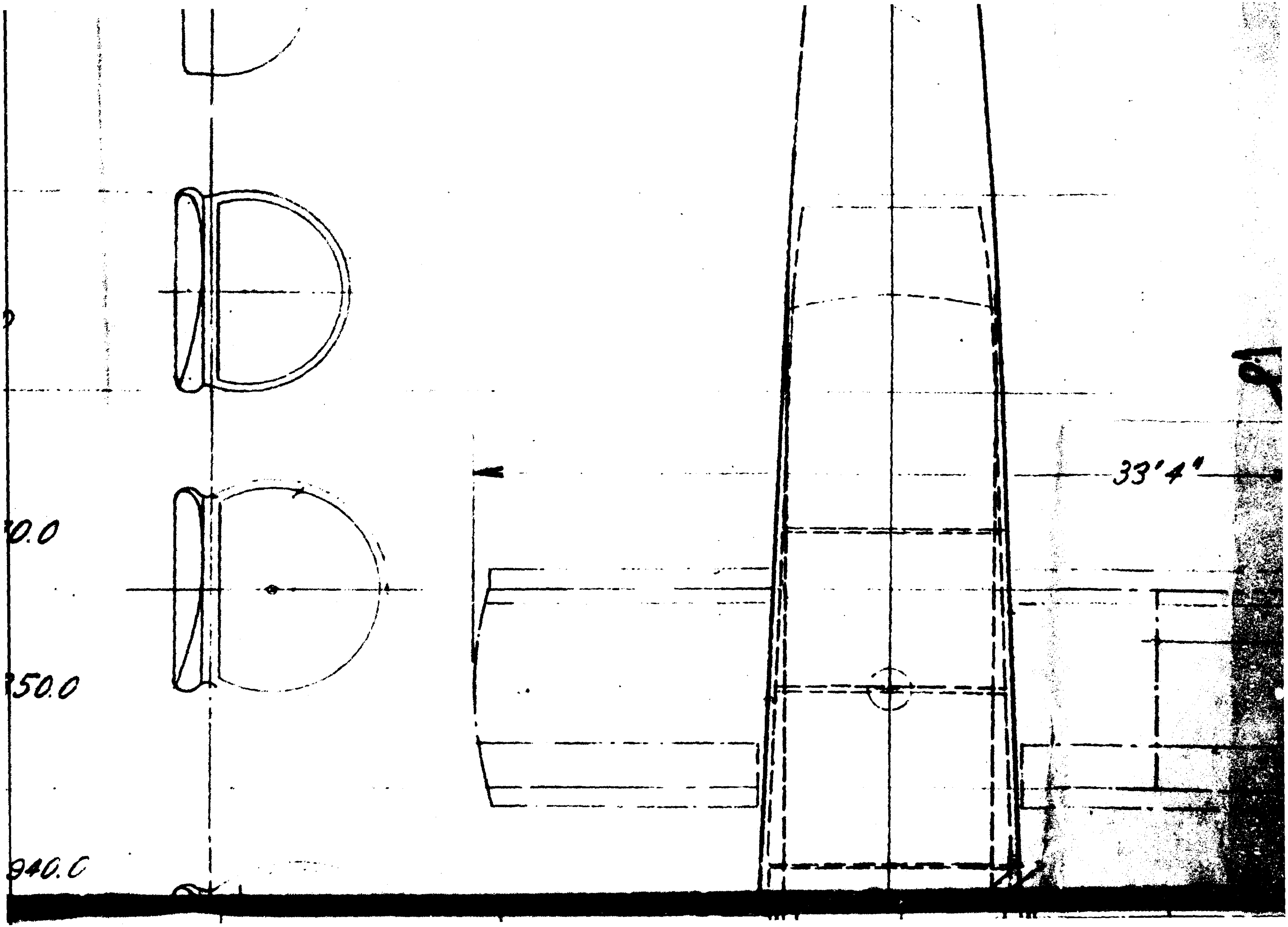
BL 672.974
ELEVON
2°
2°
BL 352
L 315.426
1°
BL 215

10

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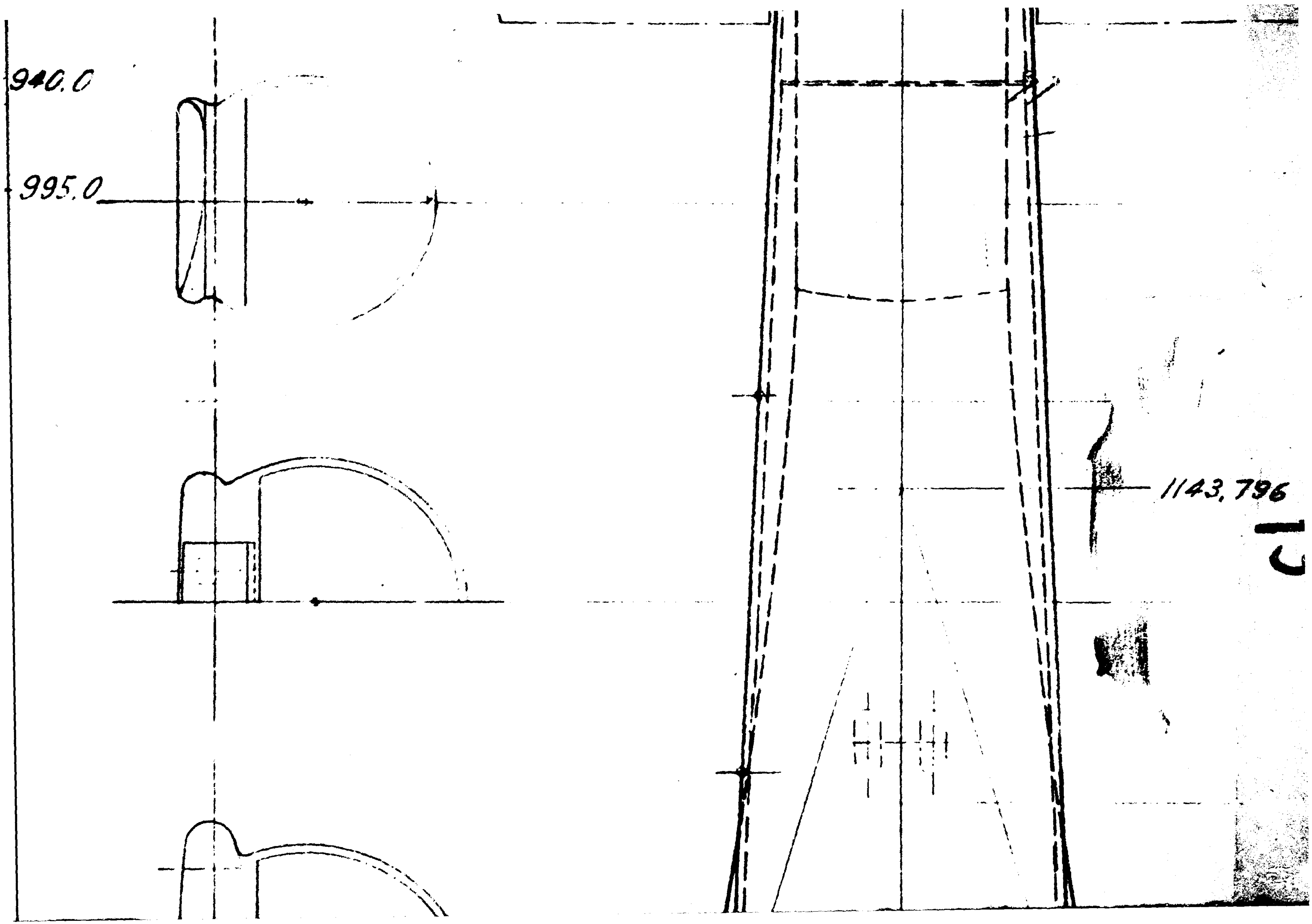
940.0



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995.0
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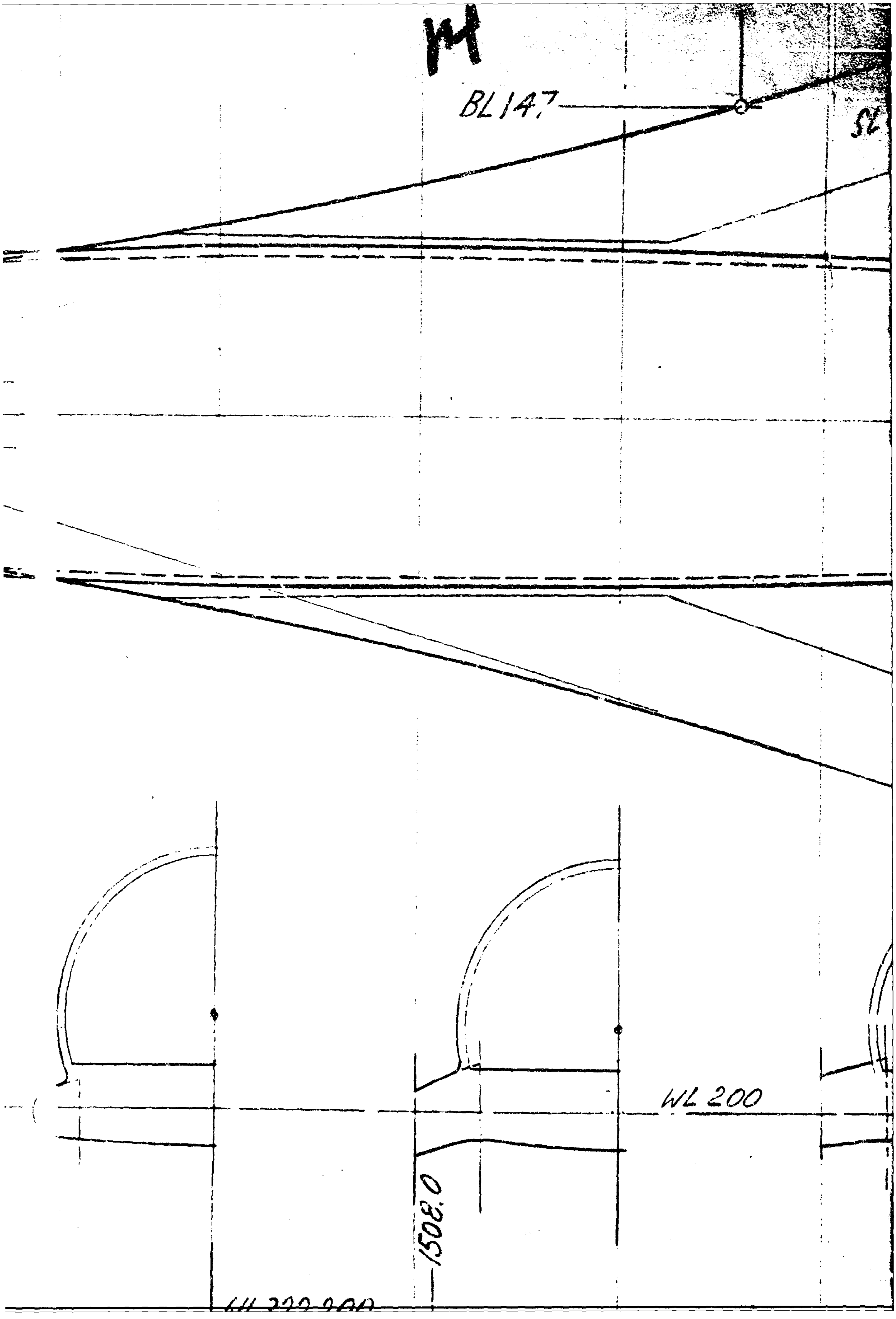
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BL 14.7
SL
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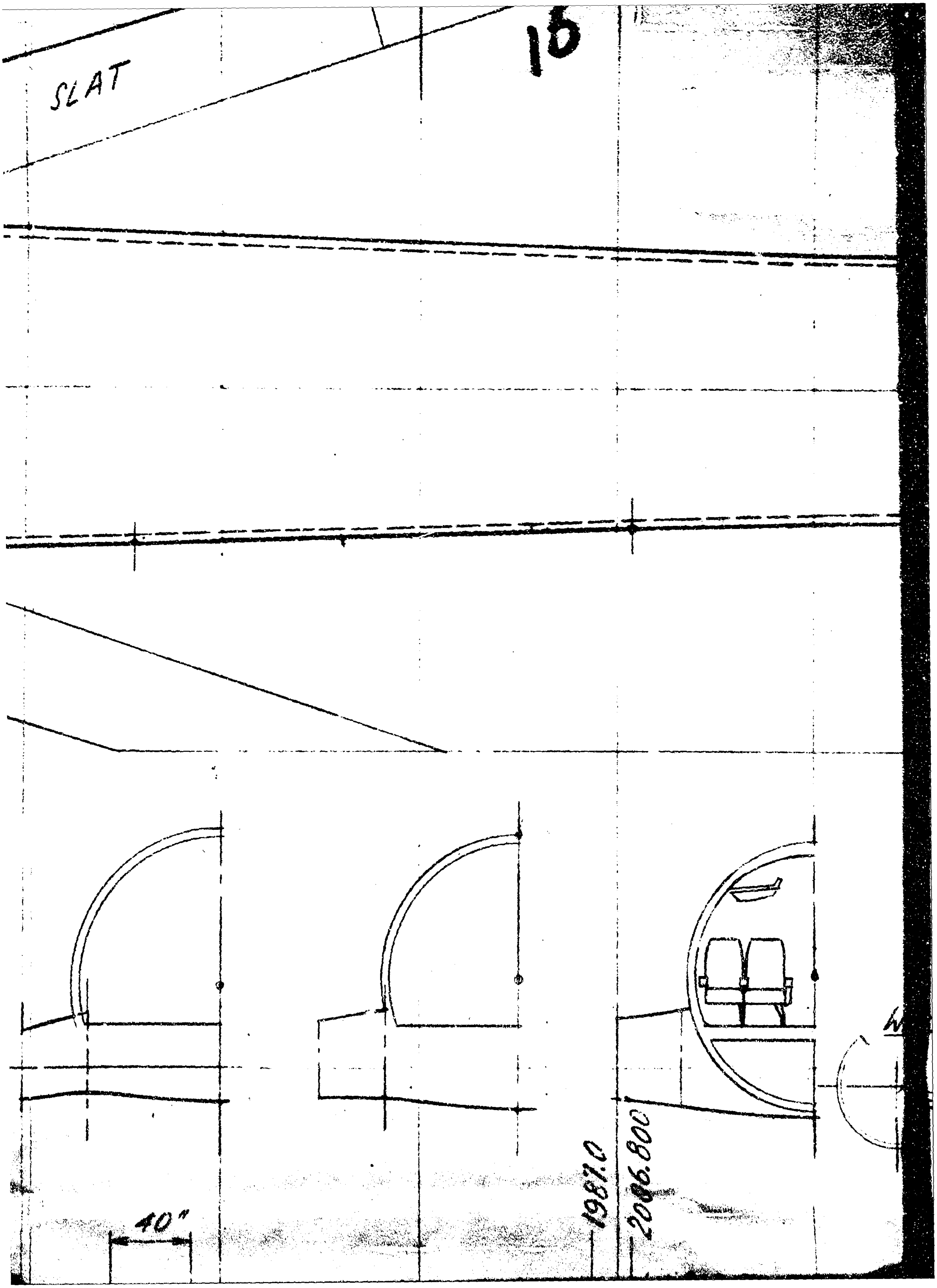

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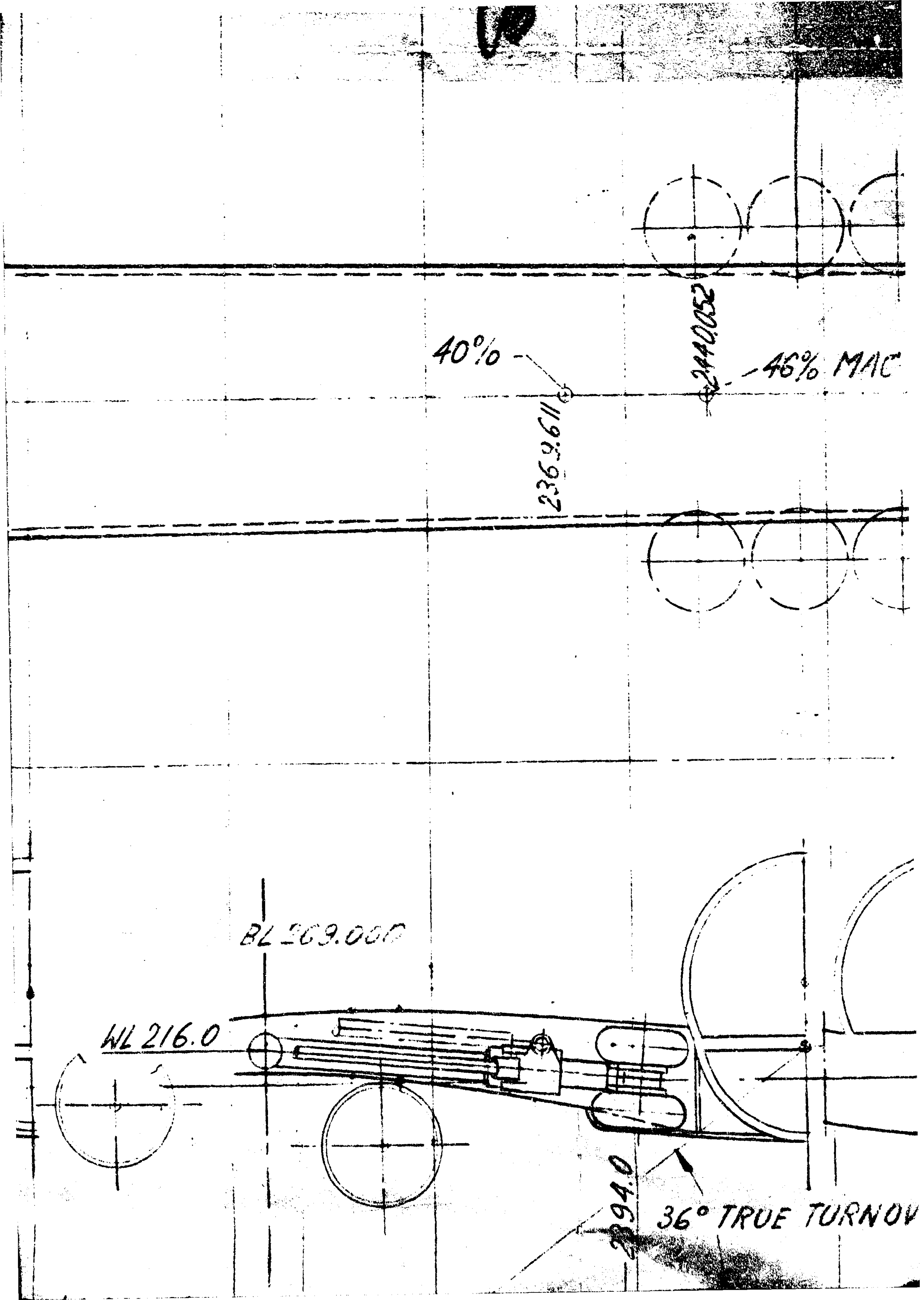
2006.800



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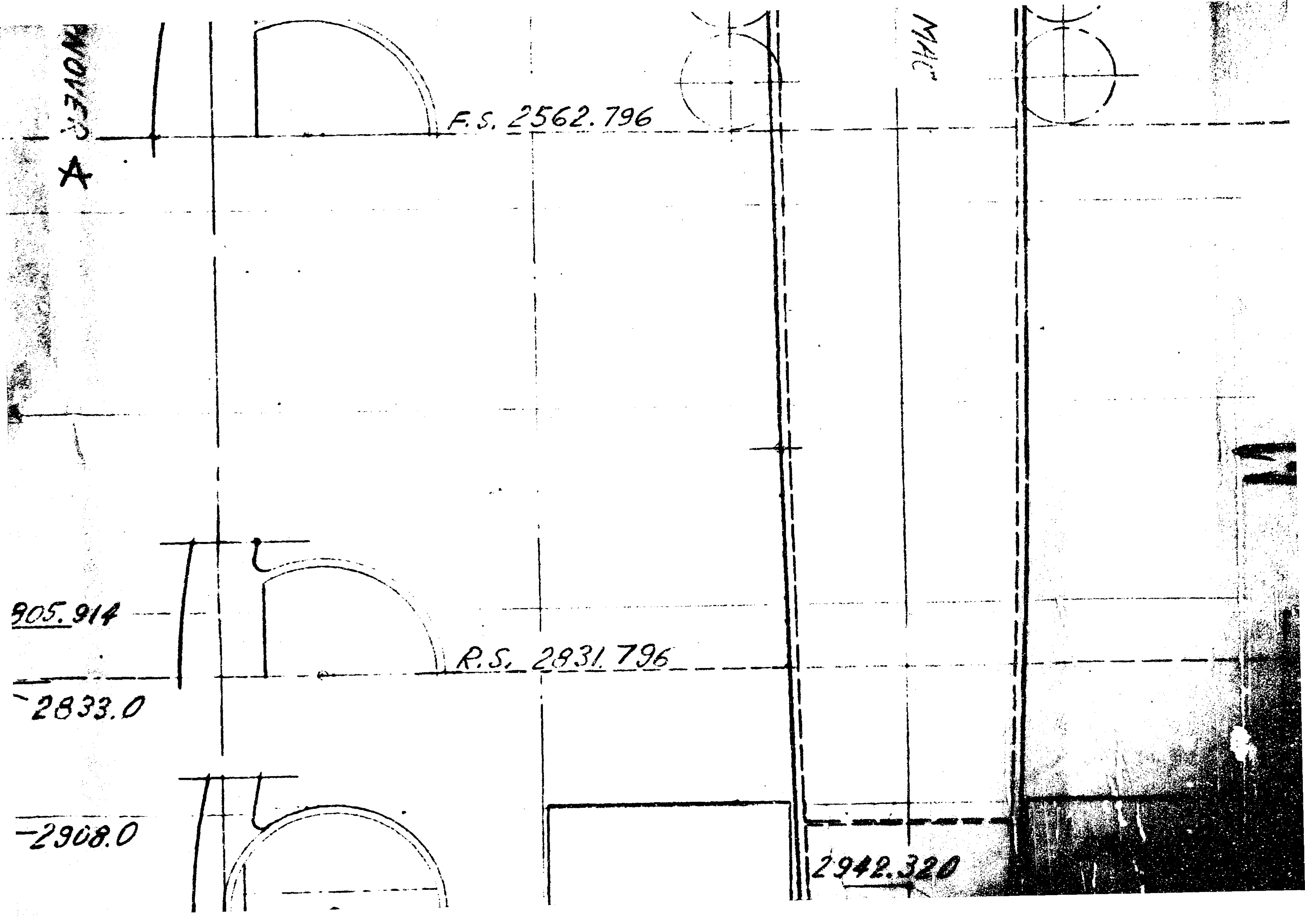
46% MAC
2369.611
BL 269.000
WL 216.0
394.0
36° TRUE TURNOV



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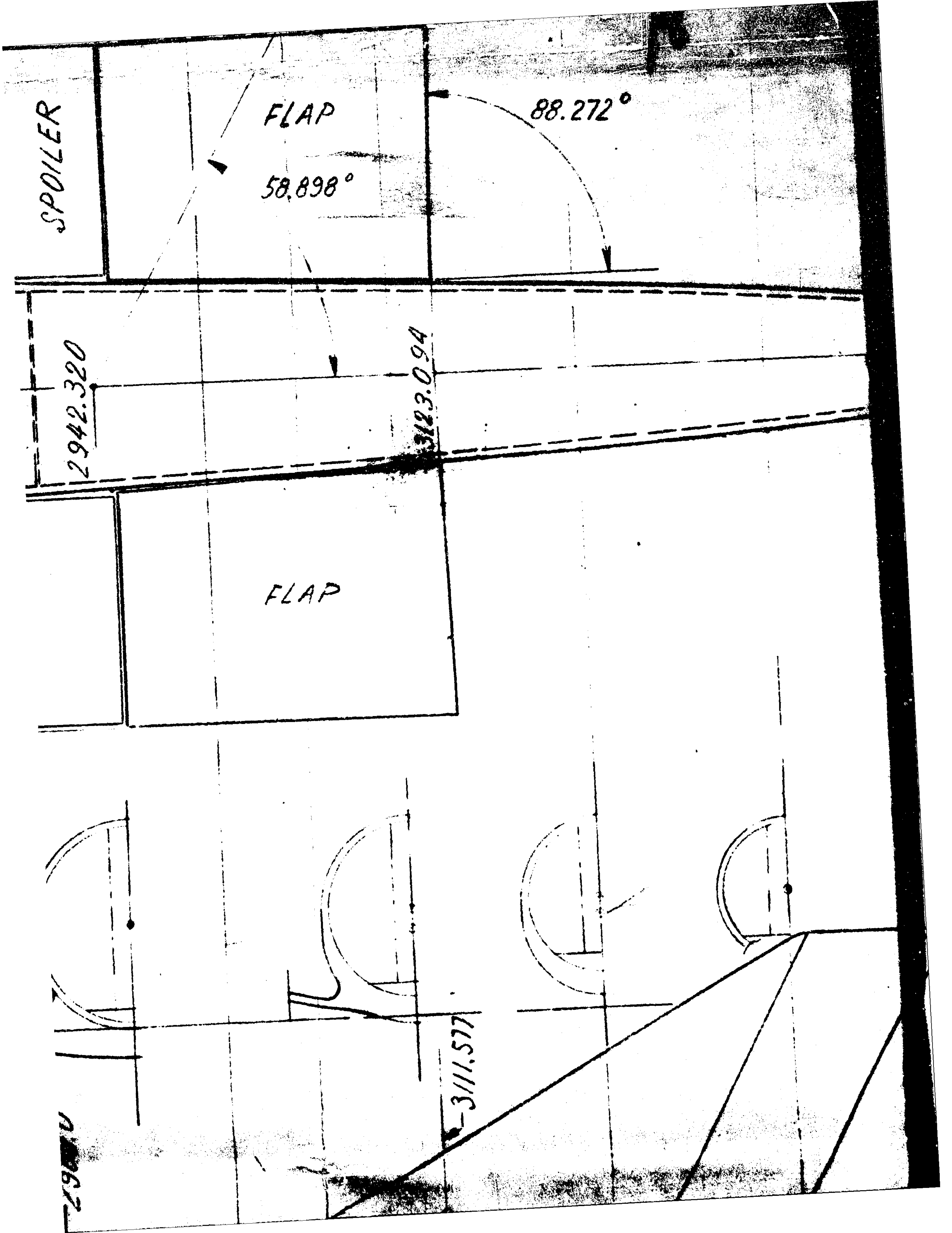
R.S. 2831.796
905.914
2833.0
2908.0
2942.320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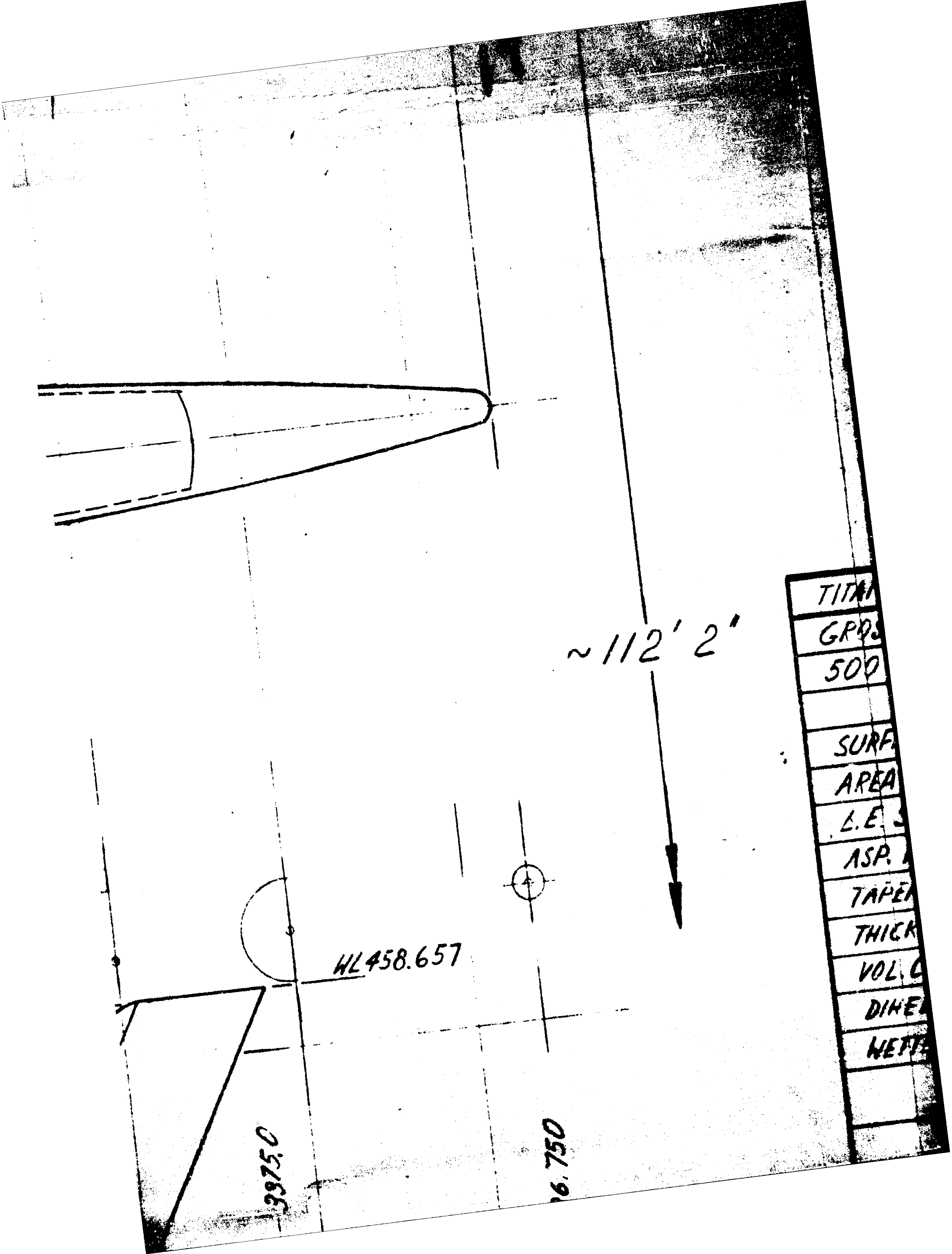
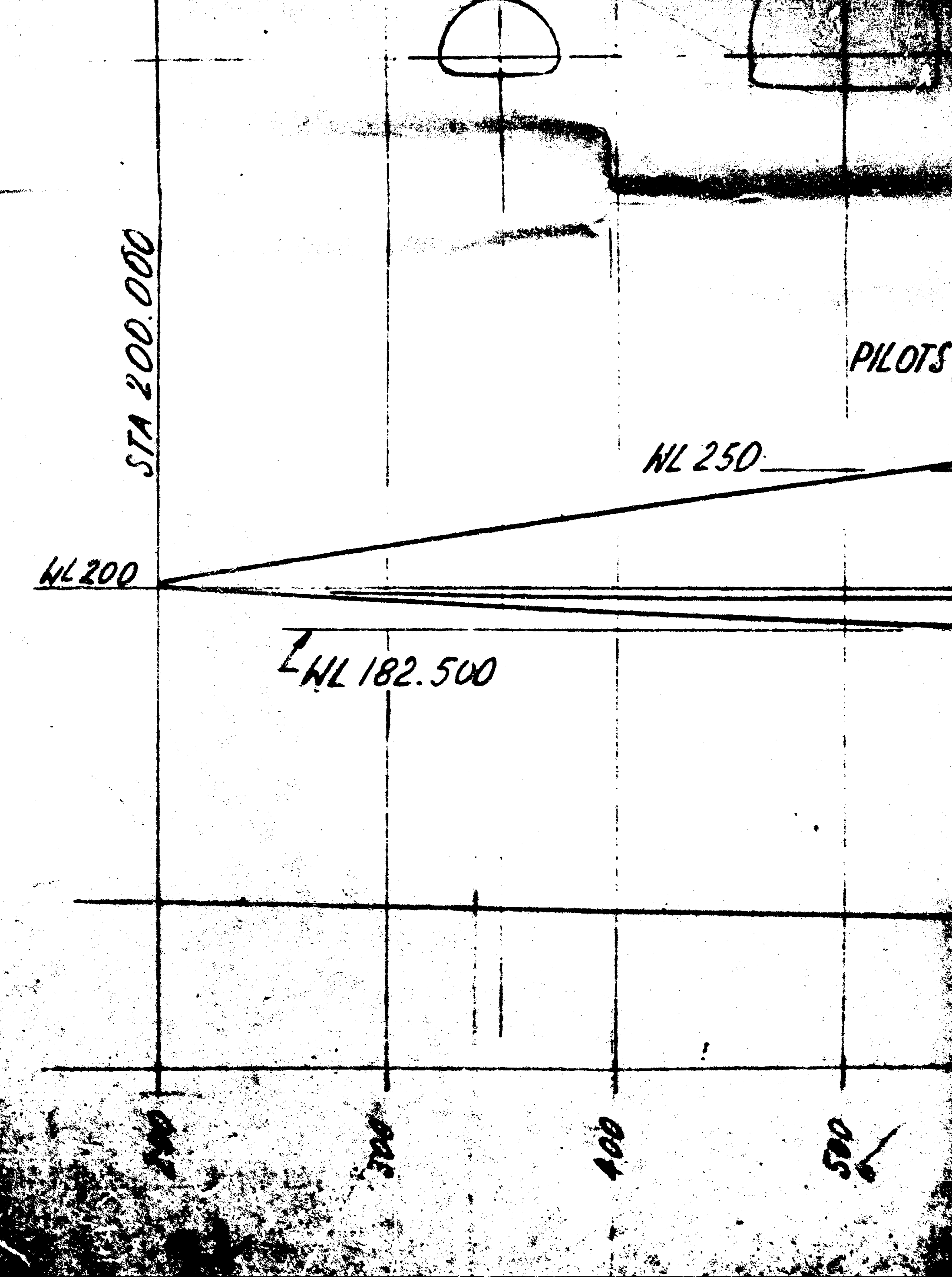
FLAP
3111.577



TITA
GROS
500
SURF
AREA
L.E. S
ASP.
TAPE
THICK
VOL. C
DIHE
WETT
~112' 2"
WL458.657
3975.0
6.750

Best Available Copy

TITANIUM, M 2.7				
GROSS WEIGHT	PAYLOAD		INT. ECO. MOD.	
500 000 LBS	43 000 LBS		215 PASS.	
SURFACES	WING REF	WING GROSS	VERT. ST.	CANARD
AREA FT²	8000	8396	340 EACH*	200
L.E. SWEEP	74° & 65°		62°	0°
ASP. RATIO	1.57		1.0	2.9
TAPER RATIO	.04		.2	1.0
THICKN. RATIO %	2¾ AVE		3	14
VOL. COEFFICIENT	—		.047	.033
DIHEDRAL	** −14½°		—	0°
WETTED AREA FT²	12636		1340	RETRAC-TABLE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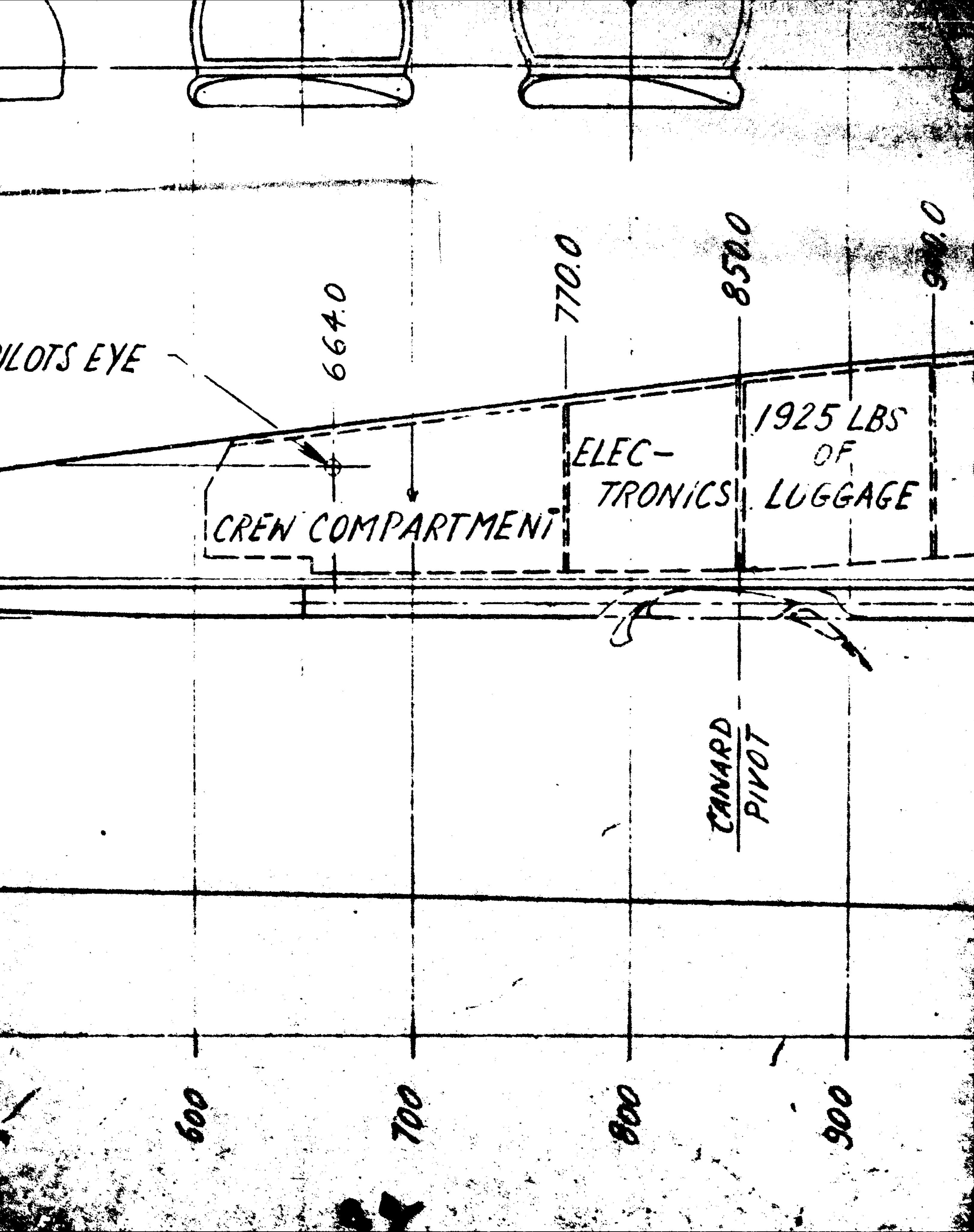
WL 250
WL 200
WL 182.500
300
400
500



PILOTS EYE
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770.0
850.0
CREW COMPARTMENT
ELEC-
TRONICS
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OF
LUGGAGE
CANARD
PIVOT
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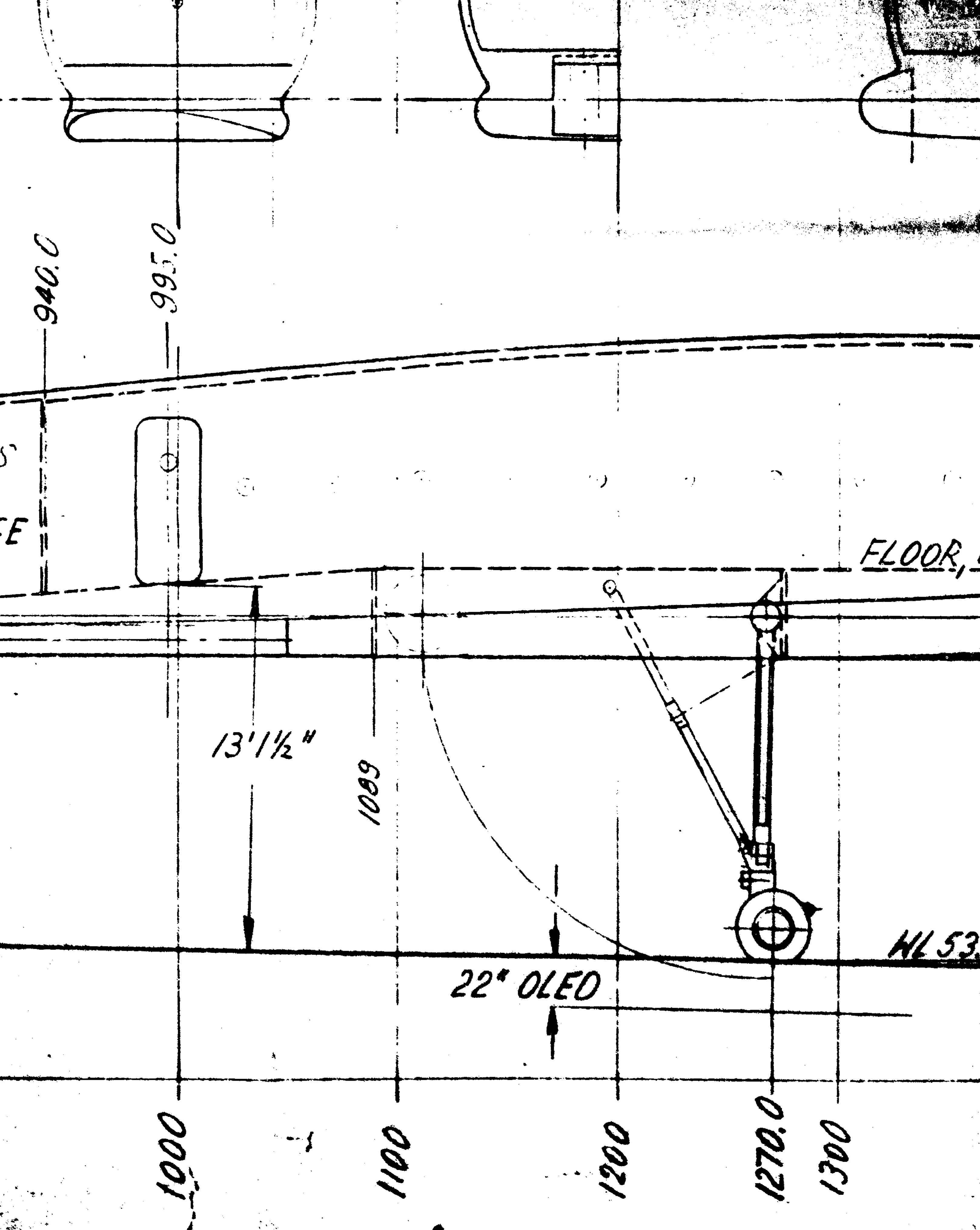
700
800
900



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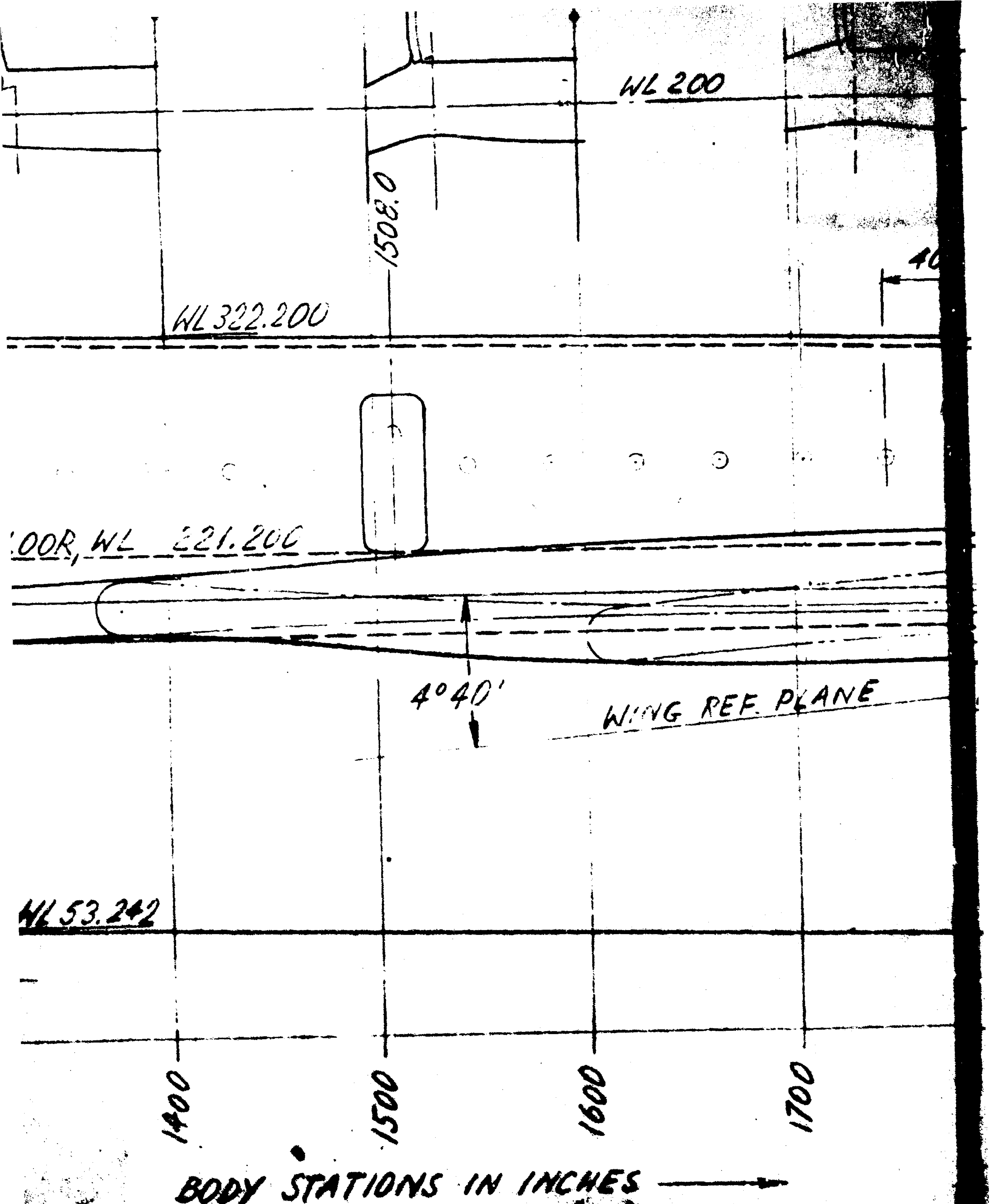
1000
1100
1200
1270.0
1300

23



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WL 322.200
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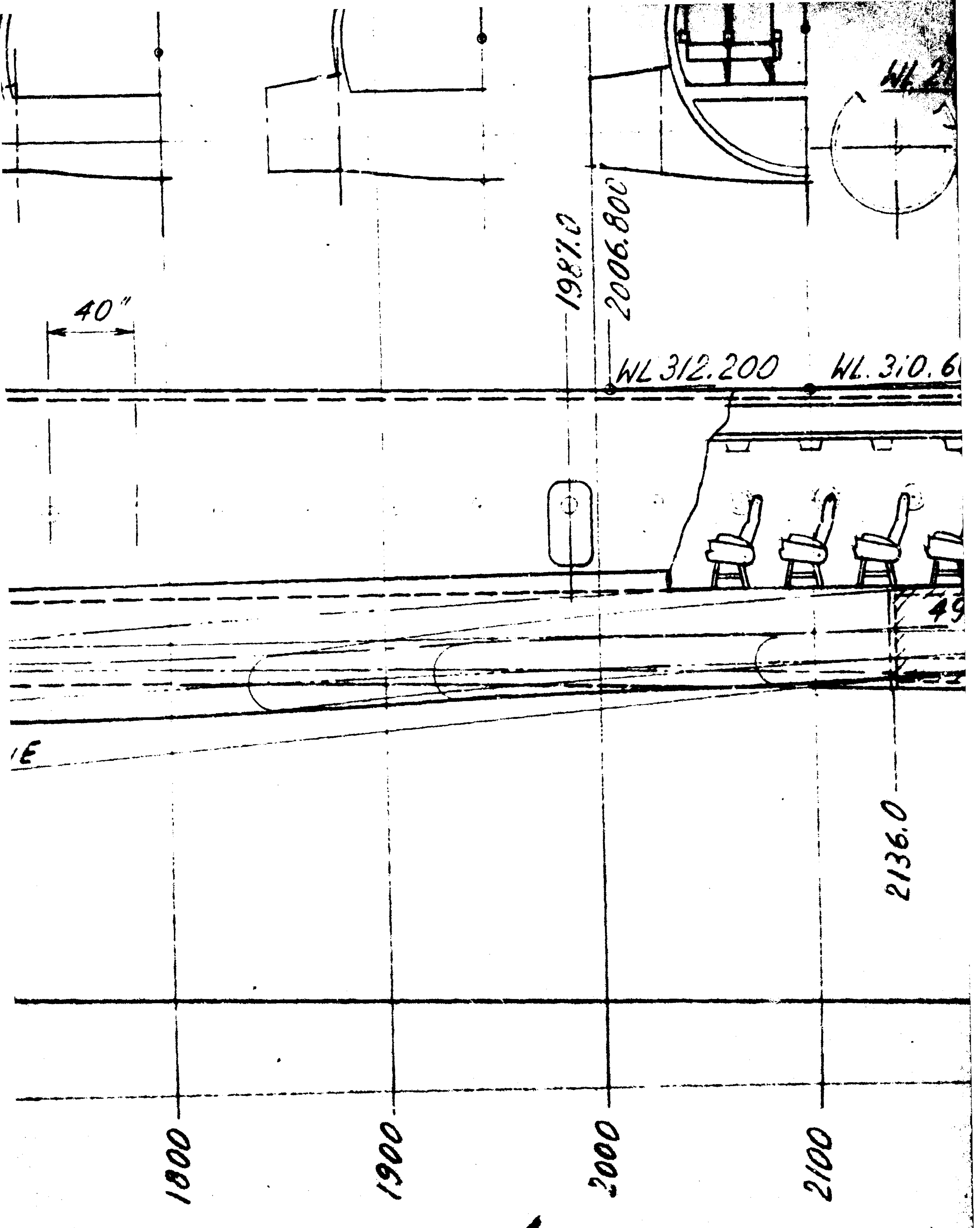
1500
1600
1700
BODY STATIONS IN INCHES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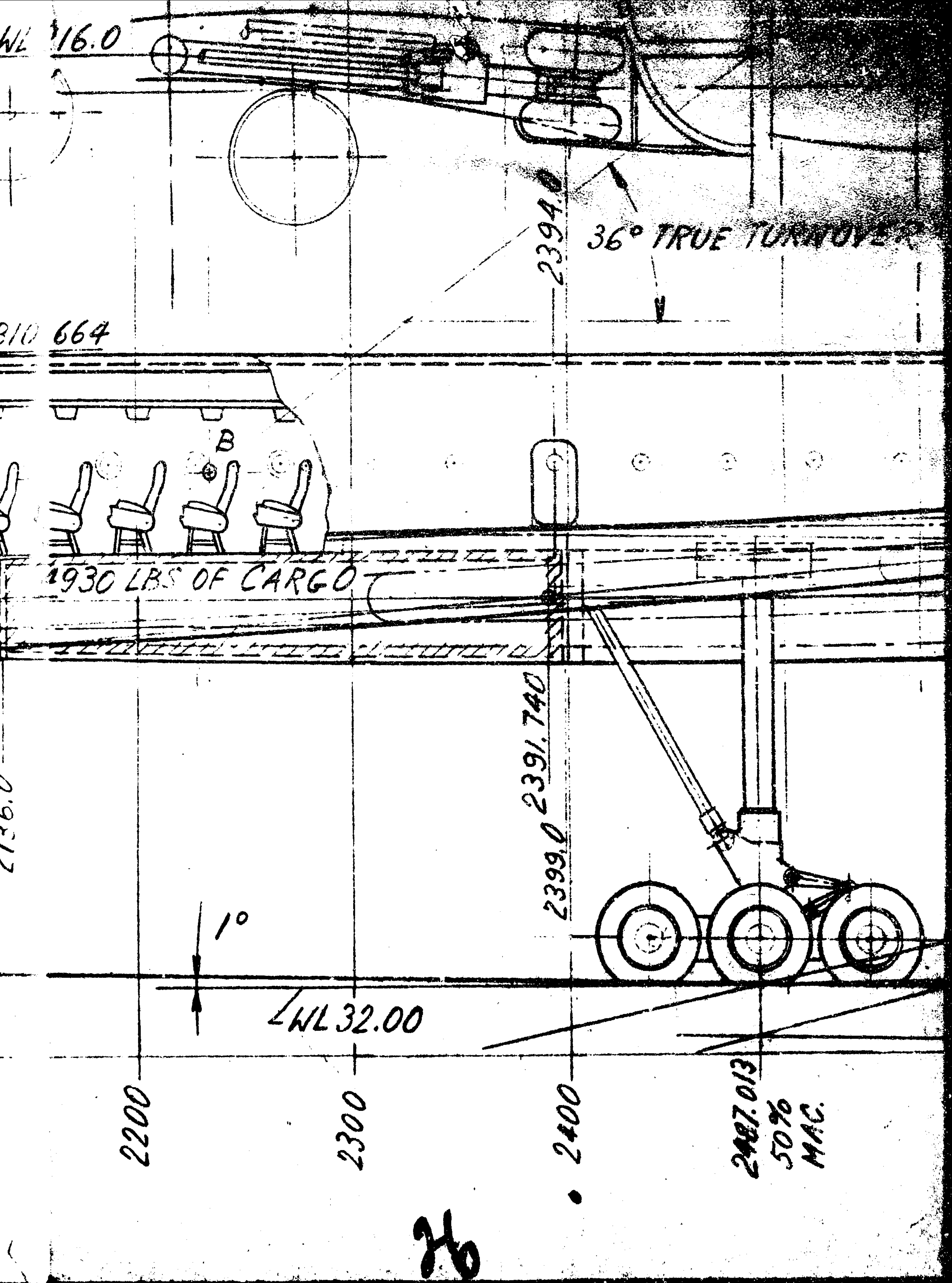
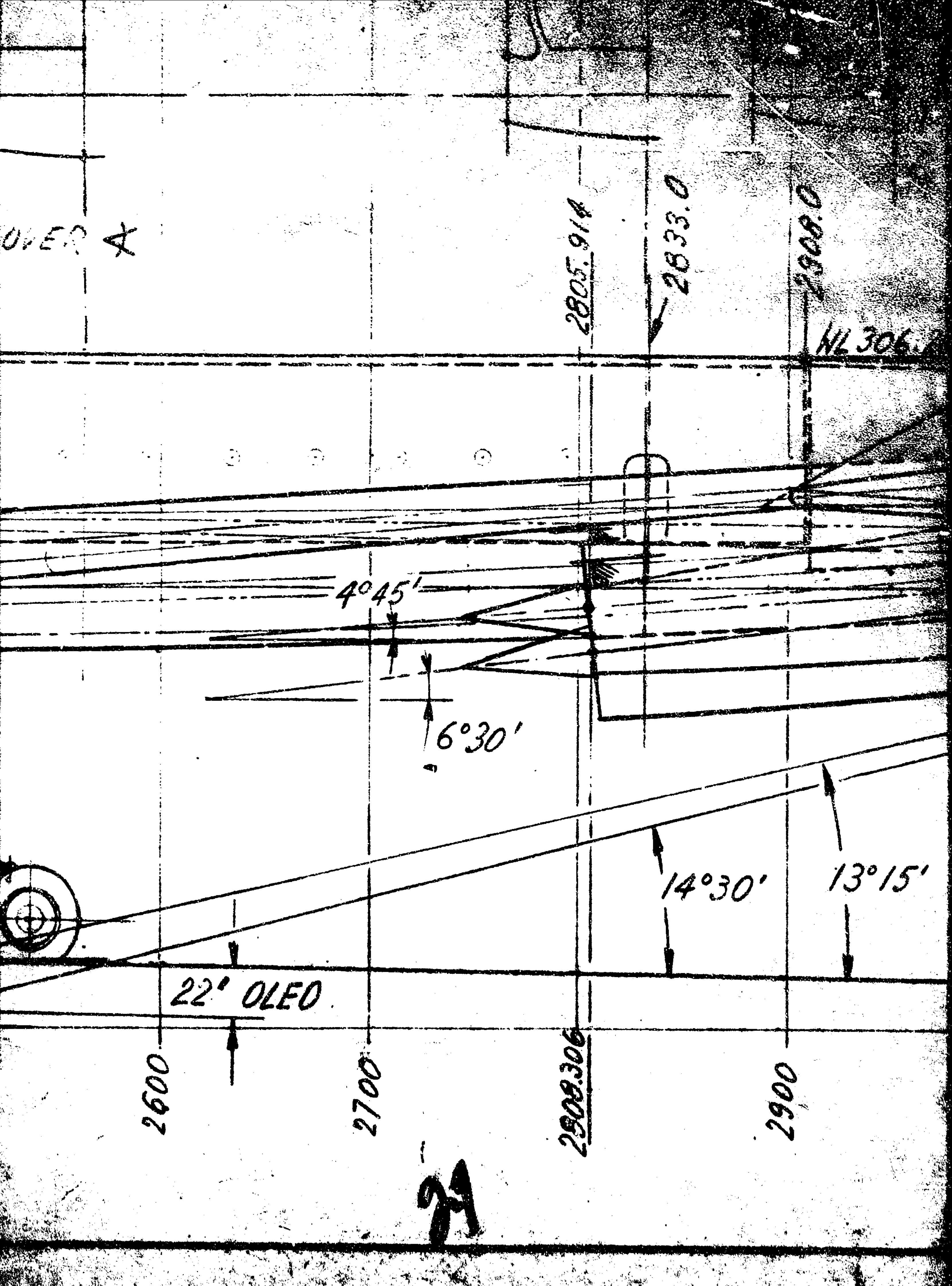
2006.800
WL 312.200
WL. 310.6
2136.0
1800
1900
2000
2100

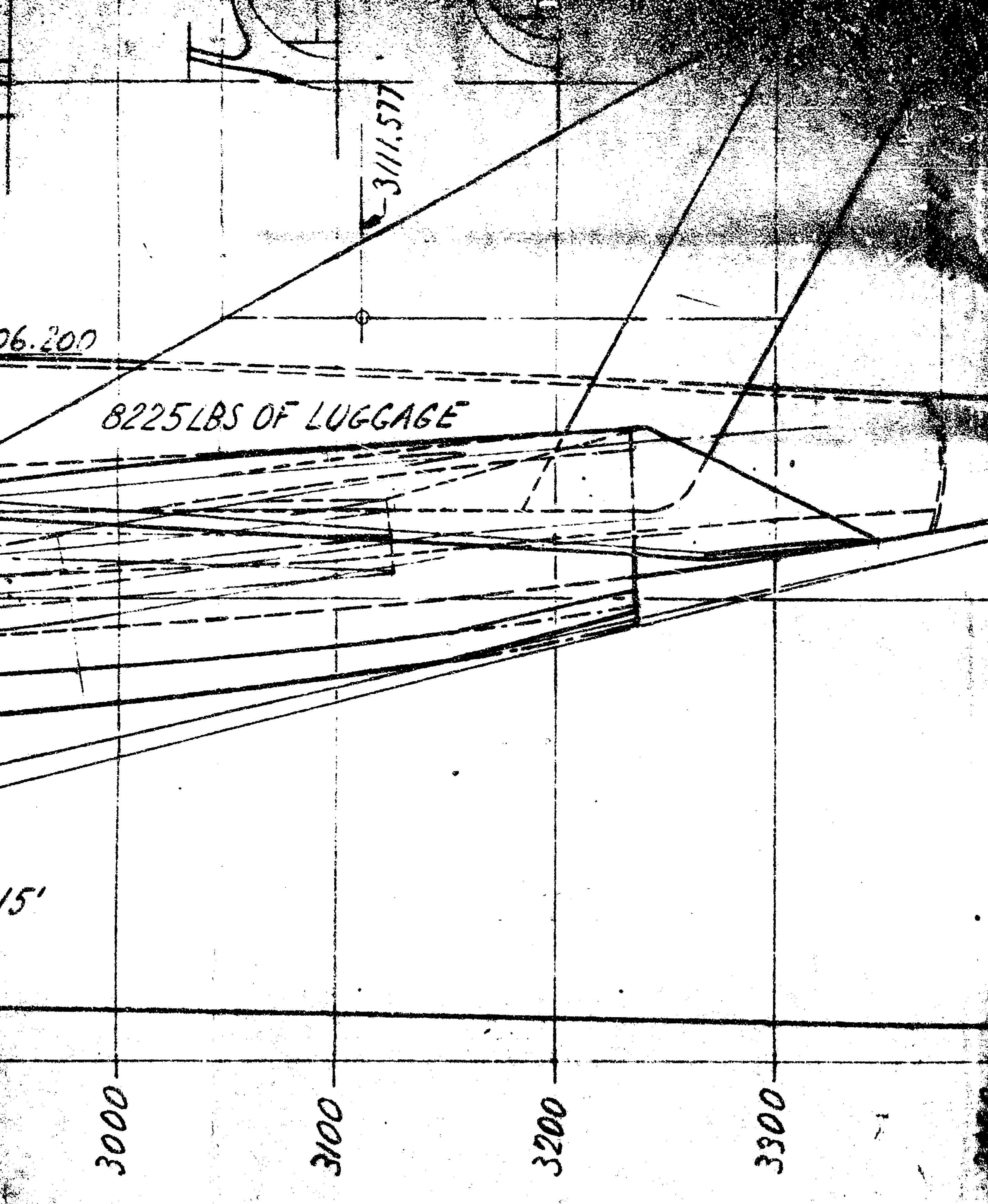


WL 116.0
36° TRUE TURNOVER
2394.0
810 664
B
1930 LBS OF CARGO
2391.740
2399.0
1°
WL 32.00
2200
2300
2400
2487.013
50% MAC.

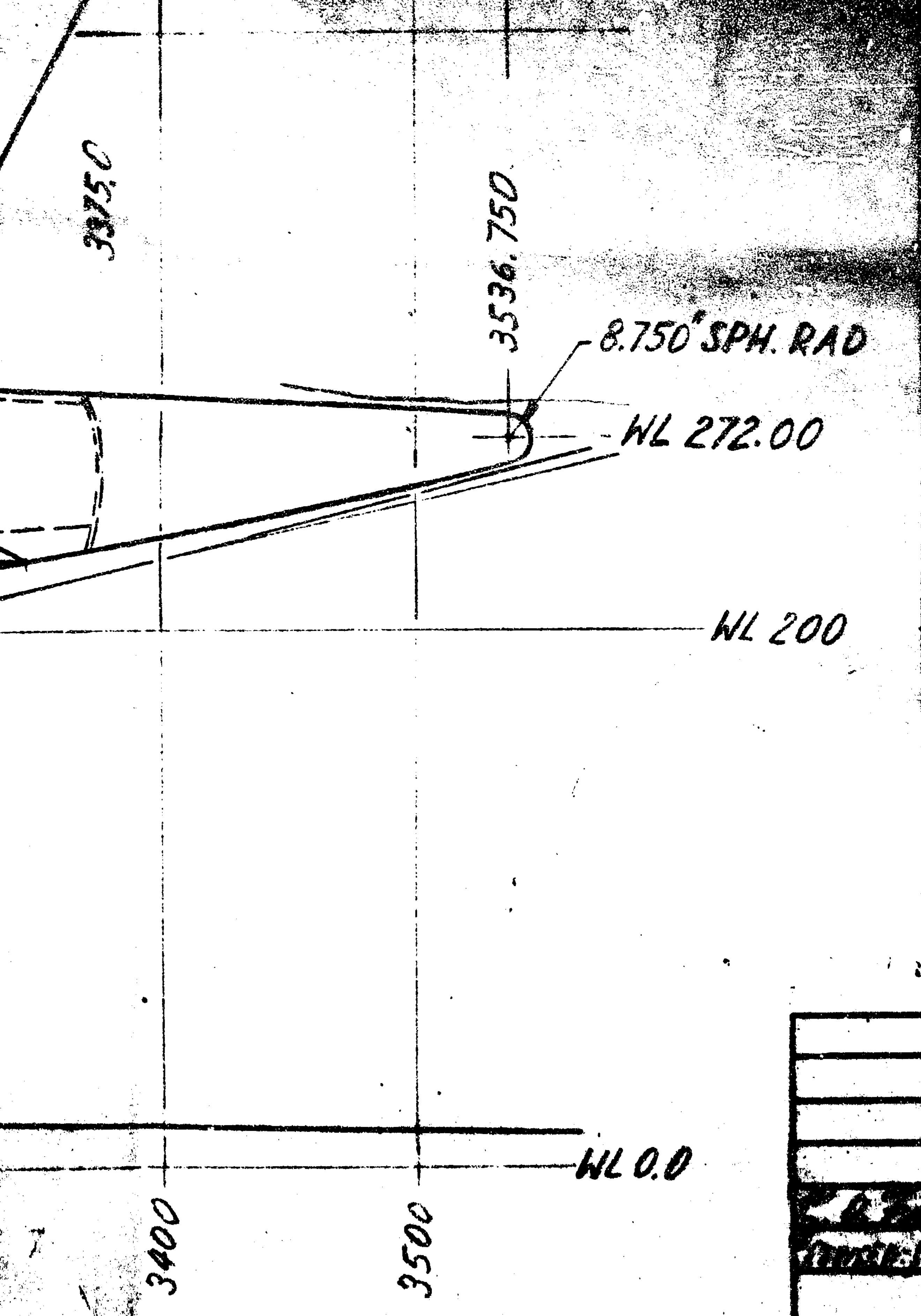
26



OVER A
2805.914
2833.0
2908.0
WL 306.
4°45'
6°30'
14°30'
13°15'
22" OLEO
2600
2700
2808.306
2900
21



28



BODY

POWERPL

LANDING G

WEIGHTS

C.G. -LIM

SCALE
1/50

VOL. COEFFICIENT			.0??	.0??
DIHEDRAL	** -14½°		—	0°
WETTED AREA FT²	12636		1340	RETRAC. TAB.

BODY	PASSENG.	SEATING	CARGO	WET. AREA
	215	4,5,6 A/B	500 FT³	7900
POWERPLANT	NUMBER	TYPE	AIRFLOW	WET. AREA
	4	TURB-JET	560 LBS	2452 TOT
LANDING GEAR	NOSE	MAIN	M. LOC	
	(2) 34×14	(12) 46×16	50 %	
WEIGHTS	TAXI-GROS.	WING FUEL	BODY FUEL	O.E.W.
	500 000	226 500	NONE	230 500
C.G. - LIMITS	SUBSONIC		SUPERSONIC	
			37% - 46%	

SCALE
1/50

* EXPOSED AREA
** OUTBD. OF VERT. STAB.

RAD

00

200

C. O. Frichol	4-27-65
REVISED: C.O.F.	4-30-65

THE BOEING COMPANY
AIRPLANE DIVISION RENTON, WASHINGTON

SCAT 15F - B7

MODIFIED NASA 15F-220; 8000FT² WING

CODE IDENT NO. 81205	SIZE J	30	
	AF		SH